A SCIENCE POLICY FOR CANADA

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A SCIENCE POLICY FOR CANADA

Report of the Senate Special Committee on Science Policy

Chairman: The Honourable Maurice Lamontagne, P.C.

Volume 3

A GOVERNMENT ORGANIZATION FOR THE SEVENTIES

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FOREWORD

GENERAL RESPONSE TO VOLUME 2

From the day of its creation the Senate Special Committee on Science Policy hoped its activities and publications would build a useful basis for policy discussion and action in Canada. This initial goal seems to have been achieved.

Many of the recommendations contained in the second volume of its report, *Targets and Strategies for the Seventies*, have been implemented or accepted in principle by the Canadian government. Other proposals were related to organizational changes. Of them, however, we said: "The Committee believes that the Canadian government should not rush in to make organizational changes or create new agencies on the spur of the moment in the field of science policy, without first having considered and decided the broad targets to be achieved and the strategies to be followed. . . . Thus, the Committee strongly urges that any important organizational changes relating to science, technology and innovation be delayed until the specialized communities immediately concerned have had the opportunity to react. . . ."[1] We are glad to note that this advice has been followed.

The discussion generated by Volume 2 went on throughout 1972 across the country. We are glad that the specialized communities immediately concerned with science policy seized the opportunity to react to our views and recommendations. We did not expect all our proposals would be accepted unanimously. Science policy matters are very complex and raise conflicting interests which are often expressed in highly emotional terms. On the whole, however, reaction to the main thrust of Volume 2 has been positive and the work of the Committee has been praised by most of those who responded to it.

It may be useful to summarize the most typical general comments we received.

One of the most ambitious events resulting from the publication of Volume 2 was the two-day forum on science policy sponsored by SCITEC in October 1972. This forum featured many briefs and panel discussions to explore the recommendations. Professor Virginia I.

Douglas of McGill University reviewed the submissions received at the meeting, of which she wrote:

> In trying to sum up my impressions from this extremely interesting collection of briefs, I am struck by the fact that the Senate Committee deserves a good deal of credit for helping Canadians focus on some fundamental issues in science policy. Certainly the scientific, engineering, and technological associations have been challenged to re-examine their own goals and to give serious thought to their responsibility for helping define a science policy for Canada.[2]

The Science Council of Canada also noted the debate engendered by the Committee's activities, and commented: "What it [the Committee] has already achieved is the status of an important and much needed catalyst of public debate on the issues of Canadian Science Policy."[3]

In its detailed commentary on Volume 2, the Association of Professional Engineers of the Province of Ontario stated:

> It is now generally accepted that the data compiled during the Senate Committee's Investigations and Public Hearings were the most extensive ever assembled in Canada and have provided a new basis for assessing the past performance, present state, and future possibilities for Canada.[4]

The brief of the Canadian Council of Professional Engineers said:

> The engineering profession considers the report of the Senate Special Committee as a valuable and necessary preliminary document towards the establishment of a science policy for Canada. . . .[5]

The views of the French-speaking scientific community were contained in a brief produced by the Association Canadienne-Française pour l'Avancement des Sciences (ACFAS), which commented:

> It is the opinion of ACFAS that this report by the questions it raises and the suggestions it offers, marks a fundamental step in the formulation of a Canadian science policy. . . . The first and specially the second volumes of the Senate report constitute the basic elements in the formulation of a real science policy in Canada.[6]

The brief prepared for the Pharmaceutical Manufacturers Association of Canada by four distinguished scientists and executives from that industry declared that the PMAC "wishes first of all to pay tribute to the quality and extent of the efforts the Special Committee has made towards the creation of a science policy for Canada. . . . [The PMAC] feels that the Committee has established beyond all doubt the historical fact that science policy in Canada in the past has been 'policy by accident' and that rationalization of the scientific endeavour within the framework of a science policy which is the result of deliberate planning is essential for the future, if Canada is to become a technologically advanced nation."[7]

The Electronic Industries Association said:

It should be remarked here that the philosophy and desirable objectives expounded so clearly in the text of the report are in almost every case viewed with appreciation and general support. ... It is noteworthy that by far the majority of the recommendations have drawn approval ranging from moderate, through considerable, to almost total support.[8]

The Alberta Society of Petroleum Geologists supported the main argument of Volume 2, "that Canada needs to increase its innovative capacity, and strengthen its manufacturing industries. ... We endorse the main conclusion of the Senate Committee, that emphasis must be placed on applied research and development along with other aspects of innovation to strengthen our manufacturing industries."[9]

A brief prepared jointly by the Chemical Institute of Canada and the Canadian Society for Chemical Engineering had this to say:

It is our view that Canada does not have, and has not had, a coherent science policy. The de facto science policy has been the sum of the individual policies of the various public and private sectors. For example, in recent years this "policy-by-accident" has resulted in emphasis on basic research, particularly in the physical sciences and particularly by governments and universities. The application of science to the solution of social and human problems and to the fostering of industrial innovation leading to economic growth has not received proportionate attention. Has this been in the long range national interest? Would these have been the priorities of a well-thought-out national science policy? We believe not. . . .[10]

The recent in-depth studies of Canadian science policy by the Senate Special Committee on Science Policy, by the Science Council and others have developed sufficient information for formulation of a national science policy. Action is now required.

THE CIC AND THE CSChE BELIEVE THAT IT IS ESSENTIAL THAT A NATIONAL SCIENCE POLICY BE FORMULATED WITHOUT DELAY. GOVERNMENT, INDUSTRY, THE UNIVERSITIES AND OTHER SEGMENTS OF THE NATION SHOULD BE BROUGHT TOGETHER UNDER THE LEADERSHIP OF THE FEDERAL GOVERNMENT TO FORMULATE SUCH A POLICY.[11]

The Committee hoped to develop such competence that its activities would help political decision makers come to grips with the issues of science policy, and now believes it has had some success in this regard. Professor Sanford A. Lakoff of the University of Toronto wrote:

. . . Pragmatic Canadian politicians must somehow thread their way through to an effective and acceptable science policy. To the extent that they succeed, the work of the Lamontagne committee could prove to have been an important milestone not only in Canadian history, but in the universal effort to make science and technology the instruments of thoughtful planning in the public interest.[12]

Some outside observers of the Canadian science policy scene have also commented that one of the biggest changes they have observed in Canada is the increased consciousness of science policy matters, which they attribute to the work of the Committee.

Here is another comment on the Committee's competence in science policy:

> In no country has the legislative branch undertaken such a thorough and detailed job. The anatomy of Canadian science and industry has been thoroughly exposed, and even if all the recommendations of the report are not equally wise, the contribution of the Committee to understanding of the problems of science and technology in contemporary society is outstanding. It can only be hoped that Canada's legislators can maintain and mature this understanding so as to give a lead through wise legislation in providing lines of progress in this period of transition in both science and society.[13]

This was written by Dr. Alexander King, Director-General for Scientific Affairs of the Organization for Economic Co-operation and Development, who not only is regarded as the father of national science policy studies but, as an examiner on the OECD team that reported on science policy in Canada, is someone who has had a long and intimate knowledge of our affairs. Dr. King also said:

> It [Volume 2] is a well-argued and thoughtful—and even erudite—attempt to balance opportunity and needs, responsibility and freedom; it delineates problems clearly and points, sometimes a little hesitantly, toward their solution.[14]

The Senate Committee expected criticism of Volume 2 because it called for change, but we did not expect to be accused of having produced a radical document, although according to Dr. Philippe Garigue, professor of political science at the University of Montreal, the reports to date have been considered by academic and government scientists "to be the most 'radical' documents ever published on the subject [of science policy] in Canada." Dr. Garigue added: "Given the history of the Canadian science system, there is nothing surprising in the fact that the science 'establishment' was shocked. What was unexpected was the way most critics of the report concentrated on detailed aspects, rather than on the overall changes that were proposed." Later, Dr. Garigue expressed surprise that the Senate reports were considered "revolutionary":

> In many ways, the Senate Committee recommendations are "new" because of the evident failure of the present Canadian system. But every one of its recommendations is already in existence in some other industrialized Western country, and there is nothing very "revolutionary" about any of them individually. What is "revolutionary" for Canada is to have them presented as a coherent whole for growth.[15]

These are just some of the comments on Volume 2; we could cite many more in the same vein. Total rejections of the report were so few and unrepresentative that they are not worth mentioning. This does not mean, however, that all our proposals were unanimously accepted. There were strong objections to several of them especially from spokesmen for basic scientists.

Some proposals we received for the improvement of certain recommendations are very much to be commended, some require further discussion and clarification, other criticisms cannot be accepted. In various sections of this volume we review the most significant of these comments and criticisms, an acknowledgment we felt we owed to the individuals and organizations who took the time to consider our views seriously and react to them responsibly. In other words, we are here continuing the dialogue that has been established with those who have expressed their genuine interest and concern for the science policy issues that are so urgent to Canada's future.

THE CONTENT OF THE PRESENT VOLUME

This volume deals with the government administrative organization for the formulation, implementation, and control of science policy and with the interfaces that such a policy requires. Chapter 19 examines four possible approaches that can be used to determine an overall organization for science policy: pluralism, co-ordination, integration, and concerted action. Chapter 20 contains our views and recommendations on the role and nature of a central machinery for concerted action. Chapter 21 describes the reorganization of government departments and agencies responsible for the implementation of specific science policies. Chapter 22 deals with the organization of the interfaces of science policy. Chapter 23 strongly invites the government to implement an overall plan for action as soon as possible, including a major administrative reorganization operation and the building and application of a decision model for science policy.

When Mr. C. M. Drury announced in the House of Commons in June 1971 the creation of the Ministry of State for Science and Technology, he indicated that the mission of the new ministry, as he described it then, was only a first step. Now, two years later and on the basis of the experience acquired in that period, we believe the time has come to take a major second step. The role and structure of the ministry must now be defined more precisely if it is to become the essential major element of an effective central machinery for formulating a dynamic science policy and continuously reviewing and controlling its implementation. The role

of the Science Council should also be reconsidered within the new context.

Another important aspect of this second step will be the reorganization of departments and agencies that are now in charge of special science policies. We have already presented some of our views on that but in this volume we re-examine and comment on the specific recommendations contained in Volume 2 and submit others.

The discussion of the recommendations in Volume 2 was concentrated almost solely on those appearing in bold type. The reader should note that not all of the Committee's proposals have been printed in bold type. There are many others calling for federal government action which have been presented in the general text of the report. The full intention of the Committee would be distorted if the latter recommendations were not taken into account. This applies also to the present volume.

The second step should also involve the organization of the various interfaces that science policy requires. They cover the relations between Canada and other countries as well as with international institutions, and between the Canadian government and Parliament as well as with the Canadian scientific community. The federal-provincial element of those interfaces is most important. Recently several provinces, including Ontario and Quebec, have developed a broader interest in science policy. This is a welcome development. It is to be hoped, however, that another federal-provincial confrontation will be avoided in this area. The best way to prevent this is to face the issue in its early stages and provide effective federal-provincial mechanisms for information, consultation, and co-ordination.

FUTURE HEARINGS AND REPORTS

This third volume completes the first report of the Committee. We previously indicated our intention of publishing a fourth volume on the R&D input to the process of social innovation—the second generation of science policy, as it has come to be called. On second thought, however, we realized that we had received little evidence in our hearings on this important and complex subject. The explanation is obvious: in 1968 and 1969, few people recognized that R&D was an important input in improving the process of social innovation or that such an effort constituted a vital area of science policy.

Since then, many segments of Canadian society have become deeply interested in improving the quality of life and worried about the efficiency of our social systems. Industry has begun to realize that it could produce better technology to serve education, health care, and

environmental quality, for instance, but it also finds that the process of social innovation presents specific impediments and that new technology cannot easily penetrate social systems. Universities are more interested than they were in contributing on an interdisciplinary basis to the R&D effort leading to social innovation. Governments are beginning to see that the organization of social R&D raises special difficulties because, according to the Canadian Constitution, the provinces are the main social innovators in the public sector. On the one hand, it would be wasteful and inefficient if each province were to organize and develop its own overall social R&D effort. On the other hand, the federal government cannot assume exclusive responsibility for social R&D programs.

For all these reasons, the Committee has come to the conclusion that it would be highly desirable, if not essential, to hold a new series of public hearings on this new and important area of science policy and then publish a separate report, and intends to seek a new mandate from the Senate for this purpose.

NOTES AND REFERENCES

1. The Senate Special Committee on Science Policy,*Targets and Strategies for the Seventies*, Volume 2, Ottawa, 1972, p. 334.
2. Virginia I. Douglas, "The Scientific Society's Look at Science Policy: A Summary of their Briefs", *Science Forum*, Volume 6, No. 1, February 1973, p. 30.
3. Science Council of Canada, *Issues in Canadian Science Policy*, A commentary on some aspects of Volume 2 of the report of the Senate Committee on Science Policy, April 1972, p. 1. The text of this commentary also appeared as part of the Science Council's Sixth Annual Report.
4. Response to the Report of the Senate Special Committee on Science Policy, Volume 2—Targets and Strategies for the Seventies, The Association of Professional Engineers of the Province of Ontario, p. 2.
5. Brief to the Minister of State for Science and Technology and to the Senate Special Committee on Science Policy on the Report of the Senate Special Committee on Science Policy by The Canadian Council of Professional Engineers, May 19, 1972, p. 2.
6. ACFAS, Quelques commentaires sur le rapport du Comité sénatorial de la politique scientifique, juin 1972, p. 3.
7. Science Policy and Industrial Strategy. A response of the Pharmaceutical Manufacturers Association of Canada to the Report of the Special Committee (Lamontagne) on Science Policy of the Senate of Canada, Ottawa, October, 1972, p. 1.
8. Comments on Volume 2 of Report of Senate Special Committee on Science Policy. Electronic Industries Association of Canada, 77 Metcalfe St., Ottawa, Canada, October, 1972, p. 1.
9. Response to the Report of the Senate Special Committee on Science Policy, Volume 2 by the Alberta (now Canadian) Society of Petroleum Geologists, October, 1972, p. 12.
10. Science Policy in Canada. The views of the Chemical Institute of Canada and the Canadian Society for Chemical Engineering, April 27, 1972, pp. 1 and 2.
11. Ibid., p. 2.
12. Sanford A. Lakoff, *Science*, Volume 179, No. 4069, January 12, 1973, pp. 151-157.
13. Alexander King, "The Lamontagne Report: An Erudite Approach to Science Policy Problems", *Science Forum*, April, 1972, p. 1.
14. Ibid., p. 2.
15. Philippe Garigue, *Science Policy in Canada*, published by The Private Planning Association of Canada, p. 19.

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ORGANIZATIONAL MODELS FOR SCIENCE POLICY

The wealth of a nation once depended on its natural resources, or the sheer size of its land, or its potential labour force; but now it is coming to depend more on its reservoirs of knowledge and its ability to organize and utilize them than on the older criteria. It is not surprising, therefore, that the best way to organize government support for science, technology, and innovation is still a subject of lively controversy, not only in Canada, but throughout the world. In the United Kingdom and the United States recent reports and organizational changes will undoubtedly contribute new impetus to the debate, and indeed the controversy in itself shows that government activities in this area differ from other policy sectors and raise unique organizational problems.

It is the purpose of this chapter to consider these problems and review the basic approaches by which other countries have proposed to solve them. In the next chapter we look at the Canadian situation and propose what we regard as the best suited organizational system.

THE PLURALISTIC MODEL

It is possible to conceive a variety of institutional arrangements for science policy ranging from centralization to decentralization. Decentralization, at the extreme, leads to the pluralistic model in which government decisions related to science and technology are taken in isolation by individual departments and agencies under the broad supervision and control of the Treasury. This is Alexander King's description of the system:

> In the pluralistic model, resources are assigned to each policy sector as a whole, e.g. defence, transportation, agriculture or health and the appropriate level of research and development for each sector determined within the sector in competition with capital investments and operational and service requirements in the same field. The overall national science policy then becomes the sum of the sectoral policies determined independently.[1]

Just such a decentralized system prevailed in most countries, including the United States, until the 1950s. Everyone who has studied the problem of public support for science, technology, and innovation has eventually rejected this model, arguing that science policy cannot be organized solely on the basis of isolated and disjointed sub-systems, for that inevitably leads to disparities of effort of growing severity. In Chapter 10 of Volume 1 we identified some of the main weaknesses of the pluralistic model:

> 1. Government agencies with important policy and regulatory missions generally tend to neglect their research missions, and agencies with small policy missions tend to overemphasize their research functions.
>
> 2. In a system relying exclusively on specific and isolated policies the inevitable compartmentalization of the federal administration produces gaps. New problems or opportunities do not always fit neatly into existing departments or agencies, which are often monuments to *past* problems or opportunities.
>
> 3. Research organizations, like others, seek to accomplish their missions completely by themselves; the striving for self perpetuation leads to growth and an attempt at autonomy—not a move toward co-operation and co-ordination.
>
> 4. This natural inclination to self-sufficiency also leads to undesirable duplication, both internationally and domestically.
>
> 5. Like all organizations, government research agencies tend to be defensive rather than self-critical. This, combined with the tendency toward autonomy, produces paralysis rather than a capacity for creative adaptation to outside change.
>
> 6. Another weakness of isolated science policies is that they can *unconsciously* conflict, particularly in the sector of public support for industrial research and innovation.[2]

These and other factors predestine the pluralistic model to produce a disjointed system and "a science policy by accident."

The Committee emphasizes that science policy should not be considered merely as the residual of all other policies or as the sum of specific science policies added up in the rearview mirror of hindsight. The sub-systems or individual science policies that constitute the elements of science policy may be considered separate for some purposes but they are also interdependent in several important respects and this must be accounted for in the *foresight* provided by an overall science policy,

specially when the necessary resources are limited. As public support for science, technology, and innovation has expanded, governments have been forced to abandon this pluralistic model and develop administrative mechanisms and central agencies to take interdependence into account, experiment with them, and evaluate them.

In the past, many observers of the United States commented that with its vast resources it could afford pluralism—and any waste that went with it. However, even the U.S. is now pressed for resources and Professor Harvey Brooks of Harvard University, one of that nation's most knowledgeable and influential spokesmen on science policy, recently warned of the cost of pluralism and called instead for a "unified, coherent strategy":

> The American system, with its emphasis on pluralism, decentralization and competition among sectors for R and D funds, performed pretty well until the mid-1960s. However, we've moved into an era where resources for R and D are limited, thus necessitating more careful planning and coordination at or near the highest government decision-making level. . . . In addition, a new and more difficult task of interweaving science policy with national social, economic and political policies would seem to call for a unified, coherent strategy.[3]

How much more important this point is for Canada—for any country with fewer R&D resources! (The R&D expenditures of the Government of Canada for 1972 were only 4 per cent of federal R&D expenditures in the U.S.)

The nature of science policy mechanisms and agencies varies according to the emphasis put on the interdependence of the sub-systems. Historically, three main alternative approaches have been tried by central science policy agencies. When the element of interdependence is considered weak and relatively unimportant, a *co-ordination model* has been adopted as the basic mechanism to link specific science policies together, with an advisory agency as the central machinery responsible for maintaining the required links. If it is accepted that interdependence should be strong, predominant, or essential, a *centralized model* has sometimes been selected as the most desirable approach and the bulk of government scientific activities have been brought together in a single agency or department. Between these two extremes there is a third possible approach, which we will call the *concerted action model*. Like the co-ordination approach it is pluralistic in character in that it depends primarily on individual agencies and departments to plan and implement their specific science policies. Not unlike centralization, however, it provides for a strong central machinery to review, assess, and approve the scientific and technical aspects of the plans and programs prepared by operating departments and agencies. The concerted action model can be used *to make co-ordination work* without having to resort to the building of large integrated organizational monoliths (or pyramids!).

Up to now, most countries have used the co-ordination approach to formulate and implement their science policies. It relies mainly on the individual initiatives of departments and agencies, constrained only by the need to submit their budgetary proposals for Treasury approval, but it also involves a central machinery composed of a variety of advisory bodies, serving as a link between operating agencies and between them and the Treasury. Consider the American experience as a typical illustration of the application of this model.

As a result of its successes in applying science and technology to the problems of World War II, the U.S. government began to build up a special central machinery for science policy a few years after the war ended. In 1950 the National Science Foundation (NSF) was created. Congress intended it to advise on overall science policy as well as to funnel grants to scientists to help keep a balance in U.S. basic research.[4] But the NSF did not develop its advisory function, as it was found that funding basic research and giving policy advice to government were incompatible objectives.[5] Sputnik convinced the United States that it was urgent to fill the vacuum. The President's Science Advisory Committee (PSAC) was established in 1957 to look after general science policy matters with a role somewhat like that of the Science Council of Canada. The Federal Council for Science and Technology (FCST) was set up in 1959 as a group of government officials responsible for co-ordinating the R&D activities of government agencies (it has been called a "science cabinet" of senior policy officials), as the Advisory Panel on Scientific Policy was supposed to do in Canada.

In 1957 the office of the Special Assistant to the President for Science and Technology was established in the White House. The special assistant was to serve as chairman of both PSAC and FCST. It was hoped that this pairing of executive activities in a single office would make an effective central machinery for science policy and science monitoring. The U.S. Congress, however, was not convinced this policymaking machinery would be strong enough. Based on the recommendations of a U.S. Senate sub-committee, a new Office of Science and Technology (OST) was established in the executive office of the President in 1962 and its director became science advisor to the President. The NSF's authority to develop national science policy and evaluate federal programs—which it had not been able to exercise—was transferred to the OST. It was hoped that "Science policy transcending agency lines would thus be shaped at the level of the Executive Office of the President, and difficulties under which NSF had operated from its establishment would be corrected."[6]

In explaining why the NSF's science policy functions were being transferred to the OST, President Kennedy said at the time, "The Foundation, being at the same organizational level as other agencies, cannot satisfactorily coordinate federal science policies or evaluate programs of other agencies. Science policies, transcending agency, need to be coordinated at the level of the President, drawing upon many resources both within and outside of government. Similarly, staff efforts at that higher level are required for the evaluation of government programs in science and technology."[7]

The OST was thus established on a par with the Bureau of the Budget, and with the important mandate described by William D. Carey:

> This Office is expected to advise and assist the President regarding: Science and technology programs, plans and policies of government agencies, taking into account the relationship with national security and foreign policy as well as the advancement of science and technology in the nation;
>
> Assessment of scientific and technical developments and programs in relation to their impact on national policies;
>
> Review, integration and co-ordination of Federal activities in science and technology; and
>
> Participation by the scientific and engineering communities in the strengthening of science and technology in the United States and the Western world.[8]

This complex organizational function is a classic example of the co-ordination model with a purely advisory central machinery. By the late 1960s many American experts on science policy were seriously questioning this machinery because it was purely advisory and appeared to be weak and ineffective. Harvey Brooks appraised the American system in 1968 as if the central machinery for advice and co-ordination did not exist:

> Although science and technology have always played a prominent part in American government, the present system of government support for technical activities has grown up in a largely unplanned way as a series of responses to specific governmental needs as they arose and were perceived through political and administrative processes. There has never been any general theory of the relations of government and science which could be called a national science policy. Rather there was a series of science policies framed in the context of particular agencies in a manner largely incidental to their principal missions.[9]

Meanwhile developments in the National Science Foundation were making it more effective for the implementation of a policy *for* science. In 1966, some four years after the NSF's responsibility for developing national science policy and evaluating federal programs had been transferred to the OST, the U.S. Congressional Committee on Science and Astronautics conducted an extensive examination of the NSF. In summarizing "What is wrong?" the committee reported:

> . . . the Foundation has not kept pace with the demands of society nor adequately oriented itself within the shifting machinery of government. . . . Fundamentally it may be said that the Foundation has functioned, and still does, in a manner that is largely passive.[10]

The Congressional committee report urged the foundation "to supplement its traditional philosophy with positive, forward-looking plans and programs." More effective management was called for. In the committee's view "the Foundation should take the initiative and be held broadly responsible for the Nation's science resources, disengaging OST and PSAC from their detailed oversight in this area" and "*OST and PSAC would thus be enabled to devote more time to national issues of applied science and development*" (emphasis added).[11]

Thus between 1957 and 1972 the NSF was shorn of its policy development and program evaluation roles but given a broader mandate for the implementation of U.S. policy *for* basic science (defined broadly enough to include some applied science). Thus it developed into what its name implied, a national science *foundation*. (Our recommendations 6 and 7 in Volume 2 proposed similar functions for the Canadian Research Board and the three foundations.)

The development of an effective central machinery for science policy in the United States does not appear to have been too successful, however.

In 1967 FCST noted in its annual report that the sheer size of the federal effort "has led to a highly decentralized operation under which most decisions are made in the departments and agencies."[12] In 1968 former Presidential Science Adviser Jerome B. Wiesner stated:

> There is no single entity of government that even has the responsibility for planning and monitoring the broad range of R&D activities that are required to support the national goals. No wonder there is so little understanding of the purpose of the country's research efforts.[13]

According to William Carey, who had a long administrative experience in dealing with science and technology as Assistant Director of the Bureau of the Budget, the American approach had failed:

> I think first of the Government's administrative and policy structure for science and technology. If our policies and strategies for R and D are hard to fathom, perhaps it is because we are not well organized. R and D is decentralized through the Federal Government. It is managed as a network which is held together loosely by the White House science office. It does not have a prime mover. Its decision-making patterns are pluralistic. As an institutional process it is not responsive to standards of balance, purpose, or priorities.[14]

The report *Centralization of Federal Science Activities* quotes Carey's description of that loosely knit network:

> Assistant Budget Director William D. Carey, in describing the budgeting process for science and technology as it is carried on in the Bureau of the Budget, admitted that from science's viewpoint, the present procedure is a "chancy process when left to run its own course." . . . Mr. Carey discussed some of the limitations in the review process within the Bureau. To a large extent, the Bureau has to have confidence in the quality and responsibility of planning and project selection at the level of the supporting agencies. It can only review the major points of justification, challenge those items which are not clearly defended and consider need, timing, and costs.[15]

In an article in *Science*, Carey concluded: "It seems to me that we need something better, something capable of shaping science goals and strategies with depth and range and visibility."[16] On another occasion he added: "Indeed, it can be said with considerable truth that we, in the United States, have been exceedingly conservative in adapting our administrative institutions to meet the assault of science and technology."[17] Most qualified observers of the American scene have concluded that the co-ordination approach did not work and have proposed a stronger central machinery "to meet the assault of science and technology."

The failure of the NSF and the OST to formulate U.S. science policy was noted in 1970 by the Subcommittee on Science, Research, and Development of the U.S. Congress in the report *Toward a Science Policy for the United States*:

> Probably the closest Congress has come to enunciating such a policy was in the National Science Foundation's Organic Act of 1950 when NSF was enjoined "to develop and encourage the pursuit of a national policy for the promotion of basic research and education in the Sciences."
>
> Subsequently, this function was transferred to the Office of Science and Technology by President Kennedy in 1962. OST's response to the duty has not been much different from that of the Foundation.
>
> The foregoing observation is not intended to be critical since *neither NSF nor OST has occupied a position within the Federal structure of sufficient authority to make its actions and/or directives effective on a governmentwide basis.*
>
> We believe it is time for Congress and the Administration to join in the development of science policy—not merely in regard to basic research, but all science and its applications. (Emphasis added.)

One hindrance to OST's operation the report noted was "that OST is frequently used for tackling immediate crises" or in a "brushfire operation." The latter is a problem not unique to the United States; it happens to all advisory central machinery that lacks "sufficient authority."

The present President of the United States has doubted the effectiveness and the need for the Office of Science and Technology or a science advisor in the White House executive office. He abolished both in his Reorganization Plan No. 1 of January 1973. The President's Science Advisory Committee has also been abolished. The change was part of "a

comprehensive program for the Executive Branch which includes a sharp reduction in the overall size of the Executive Office of the President, and a re-orientation of that office back to its basic purpose of assisting the President in top level policy and management matters."[18]

The statement clearly indicated a hankering for a return to pluralism. It said: "Increasingly, the research and development capabilities in line (*i.e. operational*) departments and agencies have been upgraded and our R&D programs have been stabilized." The implication seemed to be that science policy might not create problems in the future because the previous high rate of growth of R&D funding had been "stabilized," thus providing an overall control. In addition, the President noted that the NSF had upgraded its capabilities: "It has matured in its ability to play a co-ordinating and evaluative role within the Government and between the public and private sectors." He continued:

> I have therefore concluded that it is timely and appropriate to transfer to the Director of the National Science Foundation all functions presently vested in the Office of Science and Technology, and to abolish that office.[19]

So after it had been found that the OST could neither effectively develop a national science policy nor co-ordinate or evaluate government programs, the co-ordination and evaluation functions were given back to the NSF whence they were removed in 1962. There was some implication of a policy role for the NSF in the statement that, after the changes had been accomplished "the President will ... look to its Director as a principal advisor in science and technology matters"; but this role would involve several complicated lines of communication:

> He would advise and assist the White House, Office of Management and Budget, Domestic Council, and other entities within the Executive Office of the President on matters where scientific and technological expertise is called for, and would act as the President's representative in selected cooperative programs in international scientific affairs.

One view of what the resulting U.S. science policy machinery will look like after these radical changes is presented in Chart 16.

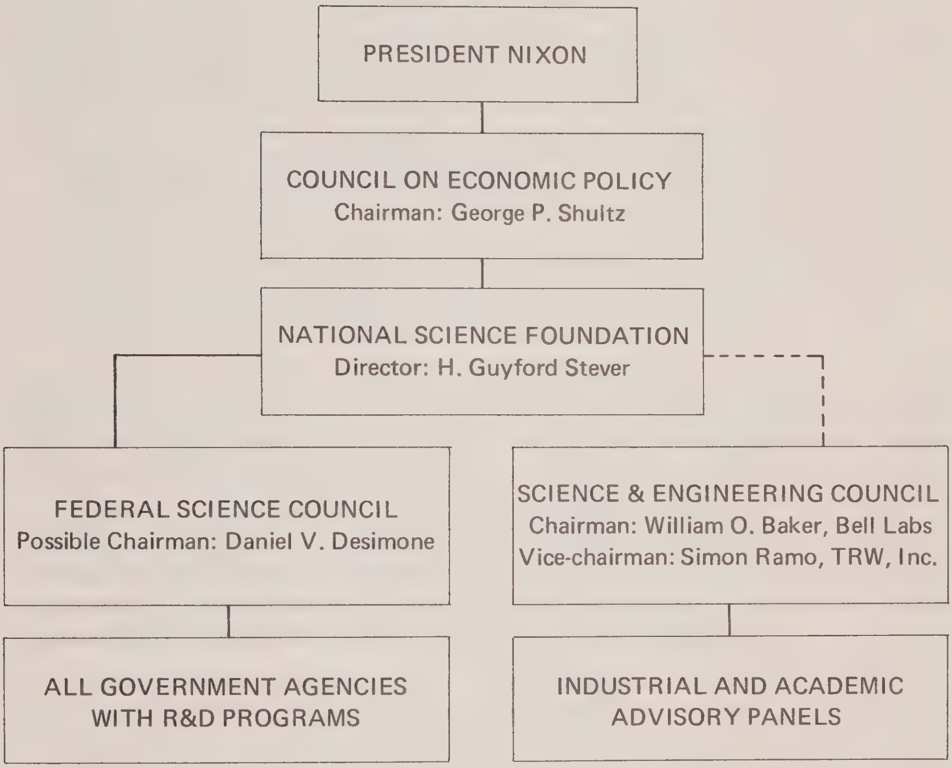
The new American system presents obvious dangers. J. Herbert Holloman, a man well versed in U.S. science policy affairs, has expressed concern about the conflict of interest implicit in Dr. Stever's diversified responsibilities:

> A question now is whether H. Guyford Stever, Director of N.S.F., can be expected to administer the Foundation, which obviously has a stake in overall science policy and allocation of science resources, and still be an unbiased advisor to other agencies and the President?[20]

A news release from the NSF in February 1973 described the director's duties in the field of civilian research and development. He would:

> —Appraise the overall effectiveness of ongoing Federal and National R&D efforts to advance national goals through science and technology.

CHART 16



SOURCE: *Business Week*, February 3, 1973.

> —Make recommendations on policy and program actions necessary to achieve these national goals through science and technology. The Director of the Foundation would form an Office of Science Policy to consider such matters. The Director would report to the President through George P. Shultz, Assistant to the President [for Economic Affairs].
>
> The NSF would continue OST emphasis on the science and technology base for national domestic R&D in such fields as energy, natural resources, health, social systems, transportation, communications, education, and participation in international programs in which science and technology are vital elements.
>
> —The Director of the National Science Foundation, Dr. H. Guyford Stever, would serve as a focal point for the President in interaction with the academic and industrial science communities on broad matters of science policy, as well as in selected cooperative programs with the international science community. He would serve as Chairman of the U.S.-U.S.S.R. Joint Commission on Scientific and Technical Cooperation.
>
> —A Science Policy Council within the Federal Government would be formed to consider policy problems in science and technology, which affect more than one Federal agency or which concern the overall advancement of the Nation's science and technology.
>
> The Chairman of the Science Policy Council would be the Director of the National Science Foundation. Membership of the Council would be composed of policy level individuals from Federal departments and agencies.[21]

Herbert Holloman has pointed out that such a variety of functions itself might create administrative complications which could make the whole system inoperative:

> Dr. Stever has other complex political relationships to sort out as well. As Director of N.S.F. he reports to the National Science Board. But in his new advisory role he is an agent of the President to whom the Board reports, at least indirectly. And I expect several powerful and trusted Cabinet-level voices will be at the President's ear proffering advice in scientific and technological matters. This seems to be how Mr. Nixon wants it.[22]

A further hindrance to the director of the NSF in exercising a science policy role is the fact that he is *a* science adviser to the President, not *the* science adviser. When an assistant director of the Office of Management and Budget was asked whether NSF would co-ordinate all energy studies, as at one time OST apparently did, he replied "They won't . . . [it will] be handled through the Domestic Council" and NSF "would provide scientific support."[23]

The main line of communication within the new system also appears to present undesirable features. It will go through the Assistant to the President for Economic Affairs, Dr. George P. Shultz, who is also the chairman of the new Council on Economic Policy as well as Treasury Secretary. This would appear to make Secretary Shultz secretary of

science policy in addition to his other responsibilities. Such an arrangement is also likely to have the undesirable result of making science policy a sub-system of economic policy. While close links should exist between these two areas of public policy, it is also increasingly recognized that science and technology should be just as closely related to social policy and that a policy for science is needed, irrespective of economic and social goals, in order to maintain a strong scientific research capability. That is why it is a mistake to link science policy only with economic policy.

Science policy problems are no longer simple. They are no longer concerned just with the development of a technological output or with the free and open development of new science and new technology, they must now consider the complex interactions of technology and society. Reviewing the new U.S. organizational changes, Holloman commented:

> My greatest concern about the technical advisory apparatus that has been dismantled is that there is no clear evidence that anybody knows what is going to replace it to deal with the central problem of science and technology and their societal applications. I am deeply concerned about how to correct past distortions in the allocation of technical resources that have affected how we can use technology for any other purpose than defense and space.[24]

Many observers think the NSF will not easily abandon its long-established traditions and shift and extend its responsibilities—specially responsibilities it was not able to exercise before. Over the years the NSF has developed a growing expertise and sophistication as a foundation. But even in that role it has had budget difficulties.

Deborah Shapley, writing in *Science*, said the NSF still had to develop the authority to get its own programs accepted. She cited a program assigned to NSF by the U.S. President in March 1972 which produced the NSF's Experimental R&D Incentives Program (ERDIP):

> In its own minor way, then, NSF was given a chance to contribute something to White House policy-making on vital national interests—a promise that at present is not being fulfilled.
>
> A year later, however, the NSF has only received and obligated about $2 million of the $18.5 million which Congress warmly appropriated for the fiscal 1973 program. The rest has been withheld by the Office of Management and Budget (OMB). A spokesman there said, "They've made presentations to us and submitted plans which we've been going over with a fine tooth comb. . . . We were disappointed with some previous plans."[25]

"Lurking behind the ERDIP studies, policy moves, proposal considerations, and a plethora of presentations," she added, "has been the dark hand of the OMB. . . . OMB apparently is making no bones about its wish to have acceptable program plans from . . . NSF . . ." before permitting it to spend its incentive money. She quoted the late Donald

Marquis, a noted student of innovation, as saying that NSF "doesn't have the clout to carry out the experiments." Among criticisms of the NSF's ERDIP program she noted was the observation of a university adviser: "There are 12 to 20 people in the country who know something about the innovation process. None of them are among the staff." If the NSF with its highly regarded foundation-type skills met this resistance and had such difficulties in extending its range of activities to a program such as ERDIP, how much greater the problem will be when it attempts to co-ordinate or evaluate federal programs, particularly if "the research and development capability of the various executive departments and agencies . . . has been upgraded."

The powerful presence of the Treasury in the form of the OMB brings up another point. Will not Secretary Shultz find it difficult to reconcile the conflict of interest between his role as Secretary of the Treasury and his ministerial responsibility for science policy? Experienced science policy observers have pointed out the dangers of such a conflict. For instance, in their report on Canada the OECD examiners recommended the appointment of a minister for science but added:

> We do not think that this position should be combined with the Presidency of the Treasury Board. Financial considerations are, of course, important and at times dominant in science policy decisions, but it is in our view unwise to create a situation with the inherent possibility of internal conflict, in which immediate financial considerations could have the primary say in all long-term policy-making.[26]

Many American experts on science policy thought the former U.S. central machinery was largely ineffective and wanted a stronger central organization. The Administration has, however, provided a weaker one, which is likely to lead to more confusion, inefficiency, and imbalances. The new system still follows the co-ordination approach in preserving a central advisory machinery for science policy but, by downgrading it, moves back toward the pluralistic model which administrative reforms, beginning in 1957, had sought to change.

American experience reinforces our observation that when the co-ordination model is chosen, the resulting frustration caused by the central machinery's shortage of authority and control leads to what might be called a "hunting oscillation." According to Holloman:

> That could take us back to the pre-World War II period—I suppose the pendulum could swing that far—when few agencies knew how to use science successfully.[27]

Wealthy superpowers might be able to sustain the losses that the inevitable swings of the co-ordination model cause to the system, but they can be ill-afforded by countries with more modest scientific and technological resources, such as Canada. The losses suffered in such hunting

oscillations could be as severe as those caused by a science policy model frozen in some once appropriate but now irrelevant stance, unresponding to change.

The Committee believes the recent decisions of the U.S. government endanger the development of the science policy "authority" called for by the congressional subcommittee. To Canadian eyes, these decisions look like a retrograde step that might well create a situation similar to what existed in Canada when NRC was reporting to the Minister of Trade and Commerce and was responsible, among other duties which included the funding of academic research, for advising the government on science policy matters. As we showed in Volume 1, that system did not work in Canada, and we doubt it will work in the United States under more complicated conditions.

Whatever future U.S. conditions may be, we conclude from U.S. experience that the co-ordination approach with its central advisory machinery has not significantly affected the decision-making process, nor has it produced an overall science policy in that country. The main deficiency of this approach is that it provides a weak central machinery of a purely advisory nature.

THE CENTRALIZED MODEL

The frustration induced by the co-ordination approach in the U.S. has fallen heavily on science advisers to the President. Some of them, once they had left their posts, were so patently disenchanted with a purely advisory central organization that they went to the other extreme and publicly advocated a *big* Department of Science responsible for major civilian R&D programs. Mere co-ordination did not correct the imbalances of pluralism and could not produce a satisfactory science policy, they argued. The alternative was to integrate and concentrate the bulk of government R&D activities and support programs in a special department where a powerful management could enforce the integration associated with true co-ordination. The justification for this second approach was summarized in the report on *Centralization of Federal Science Activities*:

> First, organizational neatness is an appealing goal when the confusing, disordered, diverse and uncoordinated array of science activities is displayed on a government-wide organization chart. Benefits are assigned to tidying up and simplifying lines of control and authority after a quarter century of evolution growth.
>
> Second, proponents of reorganization believe that the necessary funding support can only be assured by combining presently fragmented requests in a highly visible cabinet-level position from which science can compete on more even terms. . . .

> The third motive is the need for priorities within and among scientific fields so that the results are relevant to the pressing problems of society. Diffuse organization is seen as a barrier to the functioning of any system of priority selection.[28]

The logic behind centralization is that most government science activities and support programs are as homogeneous as other major government responsibilities, such as national defence, social welfare, and agriculture, and should be organized along the same administrative lines. The integration of science activities in a single organization can solve several problems; it facilitates the planning and execution of government R&D programs and the implementation of multidisciplinary and inter-agency projects.

The United Kingdom is probably the best example of a country that initially adopted a centralized model. The Department of Scientific and Industrial Research (DSIR) was set up in 1916. It was composed of research councils designed mainly to support academic research and of research laboratories that were expected to serve the needs of ministries and industry. "In this scheme, for example, road research came under the Road Research Laboratory of the Department of Scientific and Industrial Research (the Industrial and General Research Council) and not within the Ministry of Transport; building research likewise within the DSIR and not the Ministry of Works; medical research under the Medical Research Council and not the Ministry of Health; agricultural research under the Agricultural Research Council and not the Ministry of Agriculture."[29] According to this model, ministries were expected to restrict their research activities to the solution of their more immediate problems.

Serious objections can be raised against such a model. The OECD examiners in their report on Canada firmly rejected the concept of centralization:

> We feel that it is important that large governmental research programs should be as close as possible to departments responsible for operational economic and regulatory policies for subjects such as agriculture, fisheries, forestry, mineral resources and defence. As already stressed, general allocation decisions with regard to research in such areas are essentially political rather than scientific and the closest relationship between the creators and users of new knowledge. A central science ministry would inevitably tend to be operational rather than policy oriented and its necessary size could well hold bureaucratic dangers which can make creative research extremely difficult. Sound research divisions under strong scientific leadership within the mission-departments seem to us to be inherently more sound.[30]

Professor Harvey Brooks in his book *The Government of Science* looked at integration and the creation of a big Department of Science, and then listed seven objections and seven benefits. On balance he opposed

large-scale organizational integration, but he saw that more was needed than mere hopes for spontaneous co-ordination. To reach their goals, he argued, government agencies must "individually keep their channels of communication open to the world scientific community, which they can only do by carrying out or supporting research and development on their own." Taking science management completely out of government departments and into some form of central management "cannot be an effective alternative to the complicated and often frustrating process of arriving at a national consensus."[31]

Despite his belief in central planning and co-ordination, Dr. Brooks rejected the concept of a centralized model:

> The function of central planning and coordination for science in the federal government is not to control the substance of the scientific activity in the nation but rather to ensure that the scientific enterprise as a whole develops in a way which is most responsive to the needs of the country and regulates itself responsibly. This function includes making sure that the needs and opportunities in science are made known and receive the proper attention in the process of arriving at a consensus on what the government should do. In the final analysis, continued and increasing support of science by the federal government will depend upon its continuing ability to demonstrate its social utility.[32]

Even proponents of big Departments of Science recognize that full and complete integration is undesirable, if not impossible. For instance, Dr. Donald F. Hornig, a former science adviser to President Johnson, who favoured such a department, was quoted by *Chemical and Engineering News* as saying that it "would be a dreadful mistake to concentrate *all* of our scientific activity within a single agency."[33] [Emphasis added.]

The U.S. Congressional Subcommittee on Science, Research and Development in its 1970 report *Toward a Science Policy for the United States* also rejected the centralized model. The subcommittee recalled that "Federal science policy has thus far been based on the principle that control of the support for science and technology should not be centralized." Elaborating this point, the report declared:

> No one or two agencies should be responsible for federally sponsored research—nor should all those whose chief mission is research, such as the National Aeronautics and Space Administration, National Science Foundation, National Institutes of Health, Atomic Energy Commission, National Bureau of Standards, Environmental Science Services Administration, Coast and Geodetic Survey, etc., be regrouped and housed under a single administrative roof.[34]

We note also that although initially the British government accepted the concept of centralization there has been a steady drift away from the first attempt to concentrate the bulk of government R&D activities and programs in a single department. Major changes were made in 1964 and again in 1965. The Ministry of Technology was created to be responsible

for the major part of the former DSIR activities and research stations, for the provision of funds to the Atomic Energy Authority and to the National Research Development Corporation, and for government relations with the electronics, telecommunications, machine tool, and computer industries. The Department of Education and Science became responsible for government financing of the research councils. Under the new organization the Ministry of Technology, the Department of Education and Science, and the Ministry of Aviation would have been responsible in 1964-65 for 94 per cent of all government funds for civil research. Although this arrangement provided for a heavy concentration of responsibilities in a few departments, it was a weakened application of the concept of integration or of the centralized model.

Despite this concentration the need for a special co-ordination mechanism still existed. The Council for Scientific Policy was designed to advise the Secretary of State for Education and Science in the exercise of this responsibility for the formulation and execution of government scientific policy. The Cabinet had its own science adviser assisted by the Central Advisory Council on Science and Technology. But these coordinating mechanisms did not seem to work any better in Britain than they did elsewhere. Arthur Palmer, then the chairman of the British House of Commons Select Committee on Science and Technology, asked some pointed questions during a special debate in the House in 1969:

> Who gives the advice on priorities to the Government? This is a mystery. We have tried to probe it in the Select Committee and have not had a great deal of success so far. Is it the Scientific Research Council or the Council for Science Policy? Is it the personal adviser to the Prime Minister? Who does give the final advice to Government on the big decisions? In the end, despite what my Right Hon. friend said, I suspect that it is the Treasury which makes the final decision.[35]

An editorial article published in *Nature* strongly criticized the British government's organization for science policy:

> What needs to be done? For one thing, there are obvious changes in the machinery for spending money on science and technology. The Council for Scientific Policy is in danger of seeming and even being moribund, at a time when there has never been a stronger need of machinery for evolving a strategy for the relationship between universities and the research councils. . . .
>
> The other great need for a reform of the existing machinery is in the Cabinet Office, where the Central Advisory Council on Science and Technology (Sir Solly Zuckerman's apparatus) has a toehold at the centre of power but very little influence over the departments which spend most money on science and technology—the Ministries of Defence and Technology. The trouble here is no doubt inseparable from the difficulties of operating modern governments, but it is continually absurd that there should be a central body for developing policy which has no say worth listening to on how defence research should be

> organized. And what does the Central Advisory Council think about the success of the Ministry of Technology in diversifying the activities of the research establishments? What balance would it like to strike between the development of aircraft and the development of other forms of transport? Is telecommunications research in Britain properly organized and sufficient in scale? For that matter, what should be the balance of power between the Ministry of Technology and the Department of Education and Science on the financing of research? These are all questions which need to be answered.[36]

If, as the experience of several decades has shown, total integration of government science activities in one department is undesirable, it appears from comments such as these that partial integration involving great concentration in three departments is not much more effective in avoiding the difficulties.

The report presented in November 1971 by Lord Rothschild, director general of the Cabinet Office's Central Policy Review Staff, *A Framework for Government Research and Development*, put an end to the centralized model in Britain. Lord Rothschild quoted from the Haldane Committee's Report of 1918, which had recommended a centralized structure:

> It places responsibility to Parliament in the hands of a Minister who is . . . immune from any suspicion of being biased by administrative consideration against the application of the results of research.

Then he rejected this so-called Haldane principle:

> . . . if this sentence implies that the application of the results of research should be the responsibility of the independent scientific Ministry, it should have been unacceptable in 1918 and must be now. The further implication that the objectives that require applied R&D for their achievement should be formulated by this independent Ministry, Department, Council or Committee is, of course, entirely unrealistic. The 'Haldane Principle' has, evidently, little or no bearing on the conduct and management of Government R&D in the '70s.[37]

The recommendations of the Rothschild report are intended to distribute science activities and support programs more widely within the government. To the extent that they are designed to improve the decision-making process at the micro level of government departments and agencies involved with R&D programs, they are commendable. However, the report neglects the macroscopic view and the problems of balance and co-ordination. Having rejected the Haldane principle, it goes to the other extreme and provides for a central machinery weaker even than what was recently proposed in the United States:

> So far as applied R&D is concerned, the inescapable conclusion from this report is that general oversight would serve no useful purpose and, indeed, would negate the principles put forward in the report.

> Reference has, however, been made to the Chief Scientific Adviser's co-ordinating role when projects involving R&D in one Department have an impact elsewhere. There is nothing to stop the Chief Scientific Adviser setting up *ad hoc* committees to deal with such situations or, indeed, others; and it is strongly recommended that this system be used rather than set up yet another scientific advisory organization, unless events in the future make it desirable to reconsider this question.[38]

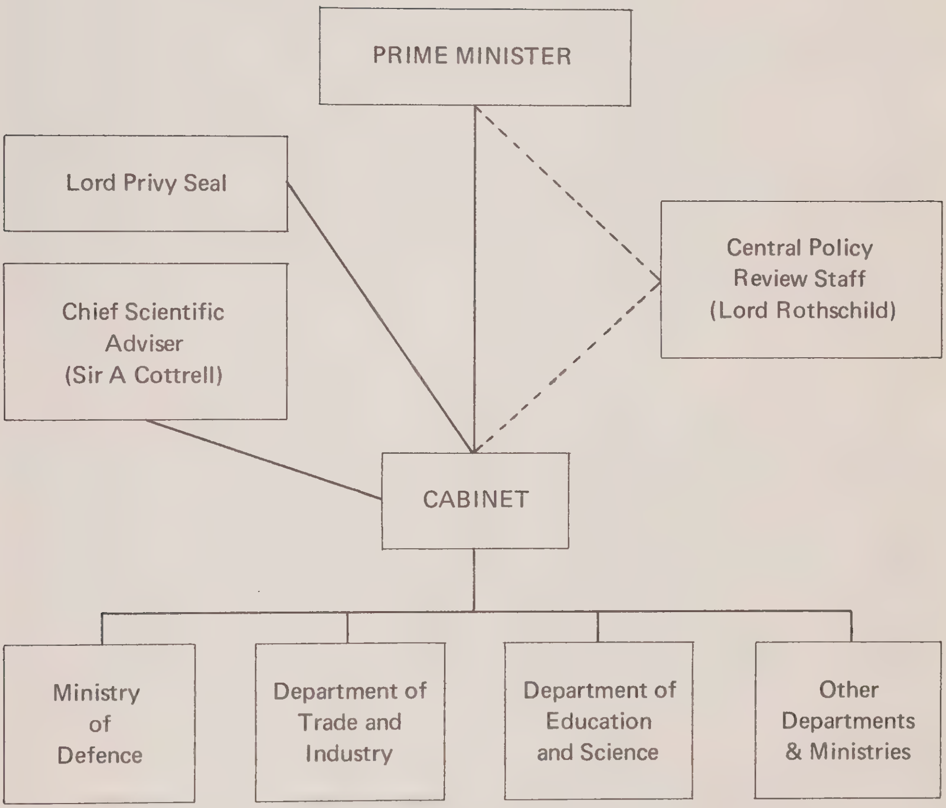
While the Committee agrees that setting up "yet another scientific advisory organization" would certainly be undesirable, it is convinced that "a general oversight" is essential and that the Chief Scientific Adviser, even assisted by *ad hoc* committees, cannot provide it with sufficient authority. Experience in Canada, in the United States, and even in Britain has clearly shown that a weak central machinery does not work; it can lead to narrow-base decision-making, neglected opportunities, and imbalances.

The British government has finally and, we believe, wisely come to the conclusion that its centralized model for the organization of science policy has been unsatisfactory. There is a danger that it will now go to the other extreme and adopt a pluralistic model whose weakened co-ordinating machinery will work no more effectively than the centralized machinery it replaces. A simplified organizational diagram of the post-Rothschild science policy machinery of the British government is shown in Chart 17.

The greatest weakness of the Rothschild report is that it leaves a vacuum at the centre and relies too much on so-called spontaneous co-ordination. This was underlined in the report *Research and Development*, issued in April 1972 by the Select Committee on Science and Technology of the British House of Commons:

> Three matters in particular cause us concern:
>
> (i) the absence of adequate machinery and criteria for decisions on national priorities for research and development.
>
> (ii) the absence of a strong, independent scientific voice in formulating policy decisions at a high level, and
>
> (iii) the absence of co-ordination between departmental research and development and the programmes of the research councils. . . .
>
> We recommend that there should be a Minister for Research and Development with his own Vote, who should be a member of the Cabinet with statutory power to examine and approve all Government research and development.
>
> We recommend that Government departments should formulate their research and development programmes on a rolling five-year basis and submit them to the Minister for Research and Development for his approval.[39]

CHART 17



SOURCE: British High Commission, Ottawa.

The British government rejected these proposals. Its main reason for doing so—its concern that ministers responsible for specific government policies should also carry the full responsibility for science activities related to those policies[40]—does not seem convincing to the Committee. In the British parliamentary system of government, ministerial responsibility is already limited not only by Cabinet decisions but also by the control over expenditures exercised by the Treasury. What the Select Committee undoubtedly had in mind was merely to transfer the control over R&D expenditures from the Treasury to the Minister for Research and Development, which in practice would not have weakened the principle of ministerial responsibility.

We believe that the swing of the pendulum from excessive integration toward pluralism is only temporary. The debate is still going on. We are more convinced than Lord Rothschild that "events in the future," even in Britain, will "make it desirable to reconsider this question." Meanwhile it is now generally recognized that the centralized or integrated model does not provide a suitable administrative structure for the formulation and implementation of science policy.

THE CONCERTED ACTION MODEL

The co-ordination approach, in which the central machinery is no more than advisory, puts too much emphasis on the *microscopic* view of science policy and a diffuse decision-making process. It produces an overall science policy "by accident" as the sum of isolated specific policies; the same faults we find in the pluralistic model. At the opposite extreme the centralized model, e.g. the Haldane principle, puts too much emphasis on the *macroscopic* view of science policy and on the "general oversight." It may produce a policy for science but it isolates science policy from government's practical missions—becomes too self-serving, in other words, and not sufficiently mission-oriented.

In the last chapter of Volume 1 the Committee recognized the need to create a science policy machinery that would bring the microscopic and macroscopic views together in a dynamic and complementary interaction. The need for this balance demands an approach to the administrative organization of science policy that allows a realistic compromise between centralization and decentralization—a fourth model, different from the three so far explored. Organizational posturing intended to "prove" that co-ordination occurs is not good enough. Rather one must strive to develop a coherent purpose for government departments by means of an

agency with the authority and leadership to focus on problems, opportunities, or functional goals. What we need is not a ballet of bureaucrats choreographed to demonstrate reaction to a suddenly felt concern but more winning teams. There are winning teams of scientists, engineers, and technologists now, but there is the human potential for many more, and an urgent need for them. The universal problem is to innovate organizational structures that will allow the effective deployment of skills and knowledge to obtain a satisfying homeostasis between science, technology, and society.

There is a need for co-ordination but it should not become a hollow word. It is one thing to set up a bureaucratic structure in which co-ordination *could* occur, and to demonstrate the provisions made for the possibility. The exercise itself is something else. Spontaneous co-ordination is the rare exception in human institutions, not the rule. The proof of co-ordination is in the output, not in the declarations of those associated with the decision-making process. It can only be proven by successful concerted action. All the evidence shows that co-ordination will only occur when the central science policy agency has sufficient authority and the right location in the decision-making structure to exert effective control and give leadership.

The Committee believes in preserving the functional responsibility of departments and agencies. But even in vertically integrated organizations, co-ordination often remains a problem and R&D programs are not always designed to serve specific missions effectively. Difficulties become even more acute where horizontal co-ordination is concerned, or when it becomes necessary to deal with new problems or opportunities created by the interaction of science, technology, and society. Existing departments and agencies are the organizational response to needs perceived in the past. It would be folly to believe that the pervasive and revolutionary force of science and technology will not some time require new departments and agencies and major shifts of focus in existing ones. These are some of the reasons why an emphasis on departmental missions should not be allowed to lead to the pluralistic model for science policy. The functional responsibility of the federal government must encompass, not be encompassed by, the functional responsibilities of departments and agencies. Hence the need for a central science policy machinery and for its full contribution to the development of policies and adjustment of specific missions so that science and technology can quickly and effectively respond to the public's requirements.

Today science and technology have major impacts on society. Technology offers a variety of choices for meeting missions, and choice leads

to conflict, beginning at the technical level (e.g. the choice of technical means) and rising to the political level. We cannot expect individual agencies pursuing specific missions to solve these differences satisfactorily. An effective central science policy machinery is required as an impartial arbiter to deal with the potential conflicts between technology and economic and social goals. For example, a fertilizer that improved agricultural productivity might produce eutrophication in nearby lakes; the technology serving an economic objective assigned to the Department of Agriculture would conflict with an economic and social goal for which the Department of the Environment is responsible.

We see an urgent need to develop a satisfactory central science policy machinery with the scope and authority to resolve the new conflicts arising from science and technology and to give leadership in utilizing this new wealth for the fullest public benefit. If this need is not met soon, public cynicism and resentment over science and technology will grow, anti-intellectualism will develop, and there will be little scientific or technological activity left to be co-ordinated. We are convinced that the recent decisions in the United States and Britain to return to the pluralistic model will help to intensify these feelings.

The Committee can only see these problems being solved by the fourth approach, the *concerted action model.* (Co-ordination can only be operationally demonstrated by an output of successful, concerted action and the name was chosen to reflect the result, not the intention. It involves the joint action of departments and agencies responsible for government R&D programs and of a strong central machinery with the authority to approve these programs. The name also reflects the fact that the model is designed for positive, creative, and timely action in focussing science or technology onto a perceived opportunity or problem.)

Robert Gilpin has described the development of this approach in France:

> . . . the Interministerial Committee [for Scientific and Technical Research was given] the responsibility for recommending to the government "the apportionment of means and resources and in particular the apportionment to be included in the budgets of the different ministerial departments concerned." Commencing with the budget for 1961, each minister responsible for scientific programs (with certain important exceptions to be discussed below), when preparing his annual budget, separates out those items for research expenditure and submits them to the DGRST [the General Delegation on Scientific and Technical Research]. The items submitted are then grouped by the DGRST into a research package or budget envelope, which is first examined by the Scientific Advisory Committee. The research budget goes to the Interministerial Committee along with the recommendations of the Scientific Advisory Committee. On the basis of the

ensuing discussion within the Interministerial Committee, the latter "submits to the approval of the government . . . draft programs for equipment and allocation of means, particularly by the appropriations to be made to the various Ministries in the national budget."[41]

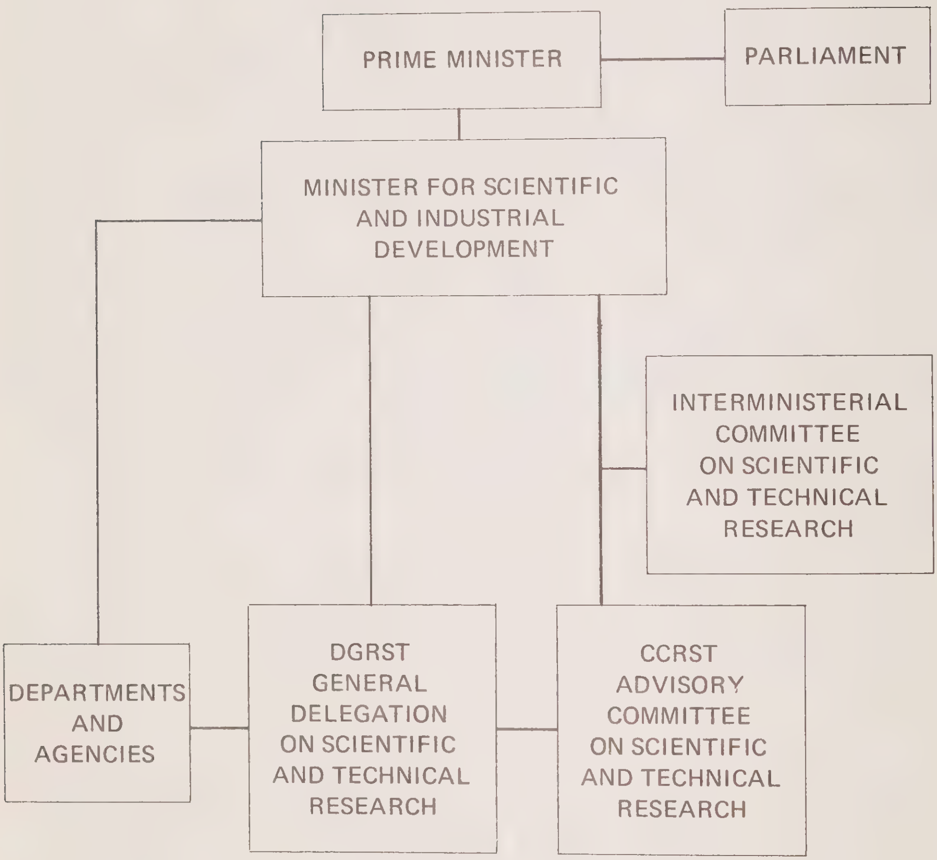
The General Delegation on Scientific and Technical Research acts as the secretariat for the Interministerial Committee and the Advisory Committee. It reports to the Minister of Industrial and Scientific Development. As we mentioned previously, the Select Committee on Science and Technology of the British House of Commons proposed a less elaborate variation of this system.

The system applied in France appears to suffer from two weaknesses. First, the research package or budget envelope submitted to the special review procedure is not sufficiently extensive. It excludes military research and, in 1967, it included only about 35 per cent of the French government's civilian R&D expenditures. Secondly, and even more importantly, the Minister of Industrial and Scientific Development is directly responsible for certain R&D programs and for operational industrial policies. To that extent, he is put in the position of having to judge his own research projects, which tends to reduce his credibility as an impartial and objective appraiser of the budget envelope. Furthermore, he may not have enough time to devote to this role because of his other departmental responsibilities. But obviously these two features of the French review and assessment procedure are not inherent in the concerted action model itself. A diagram recently published by the French government describing their concerted action model is presented in Chart 18.

The Committee believes this approach offers the advantages of the other models without their weaknesses. It has the distinctive merit of leaving the design and performance of R&D programs to departments and agencies that are responsible for operational and regulatory policies and use the research. But it also provides for a strong and specialized central machinery with enough authority to exercise an oversight more knowledgeable and positive than what Treasury Board officials can usually offer in this highly complex policy area. To offer comparable supervision Treasury Board would have to hire highly trained specialists in diverse areas of science and technology. It has been pointed out to us that the Office of Management and Budget in the United States would not be prepared to accept this responsibility. The reason, we were told, was that it would not be able to attract people of the highest calibre since they would necessarily be at the lower levels of its administrative structure. Also, the OMB is not an organization primarily involved in

CHART 18

French Organization for Science Policy Co-ordination and Decision-making



SOURCE: *France: Science Research and Development,* General Delegation on Scientific and Technical Research, Eurofab Engineering, Paris, 1972, p. 11.

science and technology and such a staff would constitute a rather unmanageable appendix to the main mission of the agency.

Concerted planning presupposes an administrative management to ensure that co-ordination takes place, to make certain that the resources and skills of the various units are integrated so that publicly-funded R&D activities match public goals, and to guarantee systematic and timely consideration of the new opportunities afforded by technology and science.

It also affords an impartial and meaningful review of R&D programs by public administrators with a specialized knowledge and interest in science policy matters. This review and assessment procedure allows for the preparation of five-year plans, for the setting of priorities within and among scientific and engineering fields, for correcting imbalances and filling gaps. It can involve the participation of the non-government sector and even when necessary knowledgeable persons from outside Canada.

Viewed as a system by which government takes decisions about science and technology, the concerted action model presents a workable synthesis of the other approaches. It maintains a pluralistic organization for R&D activities and so avoids isolating them from particular missions and practical applications. It involves a central machinery that is an essential element of the decision-making process rather than purely advisory and that is in a strong position to exercise effective control over government scientific activities and give the leadership required for timely and effective response to perceived problems or opportunities.

The essential feature of this approach is that the central science policy machinery must have budgetary control and this involves a separate science budget submitted to a detailed review procedure outside Treasury Board. Some people object to the very concept of a "science budget." Others do not agree that such a budget should be submitted to a special procedure because it would weaken Treasury Board's responsibility for the allocation of funds among competing programs and the control of government expenditures overall. The Committee does not see the validity of these objections.

In recent years, the concept of a separate science budget grouping government expenditures on scientific activities, including grants programs to the private sector, has been gaining increasing support as the way to achieve a more coherent and balanced science policy. Canada, like many other countries, publishes annual figures on government expenditures for science and technology. But several countries have found it necessary to go further than the mere calculation of past expenditures; they have found that foresight must be added to hindsight.

A growing number of governments publish special compilations of budgetary proposals for science and technology. This is only a science

budget *ex post* or a consolidation of programs proposed by departments and agencies as part of their overall budgets. But in the Netherlands, the Science Council has been asked by the government to propose the annual rate of growth of the main sectors of R&D expenditures over the following five years. Similar trends have been developed in Japan and Norway. France and to a lesser extent Belgium have already adopted more formal and systematic budgetary procedures. But the process will not stop at these initial steps. As Harvey Brooks sees it:

> . . . budgetary discussion has begun to be framed in terms of a collection of the scientific components of the budgets of all the agencies, thus producing the rudiments of a "science budget" and the concept of a "science budget" seems to be gaining ground all the time in thinking on the subject.[42]

Over the years it will become necessary to make public expenditures on R&D more visible. To be helpful in reflecting priorities, science and technology budgets must follow a consistent pattern so that changes can be seen, which would improve the discussion of policy issues by governments, parliaments, and the public. Without a clearly articulated statement such as a science budget, the consideration of expenditures proposed by individual departments and agencies can only be an occasion for the polemics of the moment. Priorities cannot be changed in one budget cycle; most R&D programs cannot be completed within a year. Thus if expenditures on R&D are not clearly shown in a special budget over a period of years, science policy will remain largely invisible and will continue to be determined mainly by the accidental and random forces of short-term considerations, which almost inevitably lead to long-term mistakes and distortions.

It is difficult to see how parliamentarians can effectively participate in science policy decision-making unless governments produce science budgets before they are approved. The interest of parliamentarians in this matter was made abundantly clear at the Third Parliamentary and Scientific Conference of the Council of Europe held at Lausanne in April 1972. The Committee was represented by Senator Allister Grosart. Among the proposals he made was one calling for early visibility of the science budget in all countries. In accepting his suggestion the conference urged that the total science spending of governments be collated and made visible before any commitments were made.

It is true, as critics of science budgets point out, that the field of science or technology is heterogeneous. But as Alvin Weinberg has indicated, "The choices between scientific fields will eventually have to be made whether we like it or not. Criteria for scientific choice will be most useful only if they can be applied to seemingly incommensurable situations."[43]

The difficulties involved in preparing and appraising a science budget should not be exaggerated, nor should they be viewed as peculiar to science. Every day government departments and agencies have to make decisions about problems that are not strictly comparable. This is the very essence of the art of government. If there were precise, invariable, and generally accepted criteria, computers could make all the decisions.

In the case of science and technology, governments arrive at a science budget, consciously or not, when departments and agencies prepare budgetary proposals for their scientific activities. The existence of a science budget would not change this important initial stage, except that it would require departments and agencies to separate out the scientific activities from their other budgetary proposals. What would change, however, is the second stage of budget-making, in which the scientific activities would be approved not by Treasury Board but by another central agency specifically designed for the purpose. This would provide for a systematic, independent review of the relevance of the scientific package as a whole and in detail to public problems, priorities, and purposes. The President of the Treasury Board and the board's members, who have other ministerial responsibilities, already have enough to do in the oversight and control of government expenditures as a whole. That is why the *responsibility* for the review and approval of the science budget, which requires special skills and detailed attention, should be assigned to a special interministerial committee presided over by a science minister and assisted by science advisers.

This special review and assessment procedure would not weaken Treasury Board's control over the government's expenditure program. Once the science budget had been approved in detail by the specialized central machinery it would be submitted as a package to Treasury Board, which would judge it in the light of other budgetary requirements. Treasury Board would be assured, however, that new and existing government scientific programs had been the subject of a detailed scrutiny by an agency that was impartial (i.e. having no vested interest in program funding or laboratories) and specialized.

CONCLUSION

The Committee has reviewed four basic models for the organization of science policy. Over the years, as science and technology assumed greater national significance and science budgets accelerated, most countries abandoned the *pluralistic model* with its diffuse decision-making process in individual government departments and agencies under the sole central control of the Treasury. Decentralized systems proved to be

inefficient and clumsy, as the interdependence of scientific and engineering fields became more evident and as a multidisciplinary and inter-agency effort began to be required to meet economic and social goals more adequately.

Many countries, including Canada and the United States, adopted the *co-ordination model*, gradually strengthening the central advisory machinery that this organizational model involves. Experience has shown, however, that such a system has not worked in practice and that the advisory machinery, no matter how strong and complex it might be, was largely useless because it did not significantly influence the decision-making process. On the basis of that experience, the U.S. government decided recently to simplify and downgrade the advisory machinery developed over the preceding 15 years. The Committee believes this recent American decision is a backward step which brings the government organization of science policy closer to the old pluralistic model abandoned in the late 1950s.

Other countries took the opposite approach when they first attempted to organize their national R&D effort more systematically and adopted a *centralized model*. Britain, for instance, sought through the creation of the Department of Scientific and Industrial Research in 1916 to centralize the bulk of its scientific activities in a single department. This helped to isolate government R&D programs from the missions they were supposed to serve. Then in the 1960s they began to decentralize government scientific activities. The report presented by Lord Rothschild in 1971 marked the end of the Haldane principle and a significant reinforcement of the trend toward a more diffuse organization of government scientific activities. In our view, it was completely justified in rejecting the traditional centralized model followed in Britain but wrong in not attempting to change and reinforce the central machinery. As a result, if the report is fully implemented, Britain will have moved from one extreme to the other and returned, for all practical purposes, to the pluralistic model abandoned in 1916.

The Committee is convinced that the *concerted action model* represents the best system for the organization of science policy in the years ahead because it synthesizes the main advantages of the other approaches without their shortcomings. We strongly recommend this model on the basis of three firm conclusions that we have reached in the course of our inquiry and after numerous consultations with experts in this area:

> *First*, a diffuse government organization for science, technology, and innovation must be maintained.

Second, a strong and effective central machinery is needed to complement the specific science policies developed by operating and supporting departments and agencies.

Third, the mandate of the central machinery must include specific authority to review and approve the science budget within the broad budgetary guidelines determined by Treasury Board.

In our opinion, after years of deliberations and discussions, Canada is now at the crossroads. We have had enough experience with the co-ordination approach to know that it cannot work effectively. A new course of action must be chosen. We hope that our country will not follow the trends recently developed in the United States and Britain. It should be obvious that in the complex and interdependent world of modern science and technology, a decentralized system, no matter how effective it may be, will not produce spontaneous co-ordination, balance, and quick response to public needs. On the other hand, the centralization of the bulk of government scientific activities in a single department or agency might lead to a generous policy for science, but would certainly not produce good science for policy. We hope that the Canadian government will adopt the basic features of the concerted action model for the organization of its scientific activities. This system provides the best opportunity to produce a policy for science *and* science for policy.

NOTES AND REFERENCES

1. Alexander King, "The Dilemma of Science Policy", *The Round Table*, no. 247, July, 1972, pp. 343, 344.
2. There is a substantial literature on this problem. On a basic level Kurt Goldstein in *La structure de l'organisme* contrasts the damaged or sick organism which *only* seeks self-preservation with the healthy organism which is prepared to undergo new experience. Organisms that are constrained, Goldstein suggests, lose "the highest form of biological existence which is freedom."
3. Quoted by Claude E. Barfield, "Nixon reorganization raises questions about role of science in federal policy making", *National Journal*, March 24, 1973, p. 410.
4. As reported by the Science Policy Research Division, Legislative Reference Service, Library of Congress in 1966, the NSF

   > ... operates under a mandate from the Congress "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes." To fulfill this responsibility, this agency supports basic research in physical sciences, engineering, mathematical, biological, medical, and social sciences; funds education in these sciences and fosters the interchange of scientific information among scientists in the United States and foreign countries; maintains a register and provides a central clearing house of information concerning all scientific and technical personnel in the United States; and develops studies related to planning of science policy. Some 42 other technically oriented Federal agencies in some degree or other engage in similar functions when conducting research and development to carry out such explicit missions in the national interest as military security, agriculture, aviation, medicine, and meteorology.

But in its concept, in its development, in its problems and in its emerging role, the Foundation represents a unique entity in the Federal panoply of technically based agencies. For in the Federal spectrum of research support, only the Foundation (and, in certain respects, the Smithsonian Institution) was established to sponsor scientific activity without any regard for practical application, and only the Foundation has the responsibility to consider policy related to and foster development of the total complex of research resources, including development of facilities and of trained manpower to help assure sustained U.S. leadership in the sciences and engineering, measured both by quality and size of effort.

From Report of the Committee on Science and Astronautics, *The National Science Foundation, A General Review of its First 15 Years,* U.S. House of Representatives, 89th Congress, 2d Session, House Document No. 317, January 24, 1966, p. 1.

5. Ibid., pp. 5.8.

The report cited in the previous footnote notes that: "In its early years the Foundation considered science policy planning primarily as data gathering" and that "The national policy formulating roles of the Foundation are not clear in relation to the National Science Board, the Office of Science and Technology, the Office of the Special Assistant to the President for Science and Technology, the President's Science Advisory Committee, the Federal Council for Science and Technology, the National Academy of Sciences, and the new National Academy of Engineering." The report later notes that "Regardless of definition, the Foundation was uniquely assigned in its organic act the responsibility for whatever policymaking would be rationalized in this area [of science policy]. Many observers of NSF development, however, have noted that the Foundation moved cautiously in this area. As one author [Dael Wolfle] has noted, [in 1957] "The Foundation is not the only Federal agency that supports research. The potential friction and jealousies confronting a fledgling agency that tried to evaluate the programs of other and frequently much larger Federal agencies are obvious."

6. Ibid., p. 6.
7. Quoted by Barfield in *National Journal, op. cit.,* p. 408.
8. William D. Carey, "Science Policy in the United States", *Decision Making in National Science Policy,* Ciba Foundation published by J. & A. Churchill Ltd., London W.1., 1968, p. 146.
9. Harvey Brooks, *The Government of Science,* The M.I.T. Press, Cambridge, 1968, p. 19.
10. *The National Science Foundation, Its Present and Future,* Report of the Committee on Science and Astronautics, Washington, 1966, p. xiv.
11. Ibid., p. xv.
12. *Centralization of Federal Science Activities,* Report to the Subcommittee on Science, Research, and Development of the Committee on Science and Astronautics, U.S. House of Representatives, Ninety-First Congress, First Session, U.S. Government Printing Office, Washington, May 29, 1969, p. 63.
13. Ibid., p. 64.
14. William D. Carey, "The Need for Priorities", *Science,* Volume 163, January 3, 1969, p. 23.
15. As quoted by William D. Carey in *Centralization of Federal Science Activities, op. cit.,* p. 69.
16. Carey, *Science, op. cit.,* p. 23.
17. Carey, *Decision Making in National Science Policy, op. cit.,* p. 140.
18. The White House, Fact Sheet, Reorganizational Plan No. 1 of 1973, January 26, 1973, Office of the White House Press Secretary, p. 1.
19. Congressional Record—Senate, Proceedings and Debates of the 93d Congress, First Session, Washington, Friday, January 26, 1973, p. S1278.
20. J. Herbert Holloman, "Diffusing Science from the White House", *Technology Review,* March/April, 1973, p. 6.
21. This refers to the Federal Council on Science and Technology or a new version which might take its place, National Science Foundation news, No. 73-104, January 26, 1973.
22. Holloman, *op. cit.,* p. 6.
23. Deborah Shapley, "White House Science: Hail and Farewell", *Science,* Vol. 179, No. 4080, March 30, 1973, p. 1311.
24. Holloman, *op. cit.,* p. 6.
25. Deborah Shapley, "Technology Incentives: NSF Gropes for Relevance", *Science,* March 16, 1973, p. 1105.

26. *Canada*, Reviews of National Science Policy, OECD, Paris, 1969, p. 410.
27. Holloman, *op. cit.*, p. 7.
28. As quoted by William D. Carey in *Centralization of Federal Science Activities, op. cit.*, p. 5.
29. King, *op. cit.*, p. 346.
30. *Canada*, Reviews of National Science Policy, *op. cit.*, pp. 409-410.
31. Brooks, *op. cit.*, p. 17.
32. Brooks, *op cit.*, p. 18.
33. "ACS symposium defines and defends basic research and deliberates its future", *Chemical and Engineering News*, September 23, 1968, p. 54.
34. Hearings before the Committee on Science and Astronautics and the Subcommittee on Science, Research, and Development, U.S. House of Representatives, Ninety-Second Congress, First Session on H.R. 4743, 1972 National Science Foundation Authorization, U.S. Government Printing Office, February, March, April, 1971, p. 830.
35. Parliamentary Debates (Hansard) Volume 787, No. 153, Monday, July 21, 1969, London, Her Majesty's Stationery Office, p. 1277.
36. "No Recess for Government", *Nature*, Volume 223, August 9, 1969, p. 549.
37. Lord Rothschild, *A Framework for Government Research and Development*, London, H.M.S.O., November, 1971, p. 19.
38. Ibid., p. 20.
39. *First Report of the Select Committee on Science and Technology*, London, H.M.S.O., April 1972, pp. xiii-xiv.
40. Government Observations on First and Fourth Reports of Select Committee on Science and Technology, Session 1971-72, presented to Parliament by the Lord Privy Seal, December, 1972, Cmord. 5177.
41. Robert Gilpin, *France in the Age of the Scientific State*, Princeton University Press, 1968, p. 202.
42. Brooks, *op cit.*, p. 25.
43. Edward Shils, "Criteria for Scientific Choice", *Criteria for Scientific Development: Public Policy and National Goals*, M.I.T. Press, 1968, p. 29.

20

THE NATURE AND ROLE OF THE CENTRAL MACHINERY FOR CANADIAN SCIENCE POLICY

The process of changing institutional systems involves diagnosis, prognosis, prescription, and implementation. There is always a danger of putting too much emphasis on the first two phases and neglecting prescription and specially implementation. In this light it is interesting to look at past Canadian experience with government organization for science and technology.

In 1916 and in the 1920s, as the second major technological revolution gained momentum, it was decided that the main objective of science policy should be the promotion of research for use in industry. The diagnosis made good sense because Canada had the natural resources and could expect to develop profitable industries from new technologies. The prescription called for the creation of an advisory council to help co-ordinate government R&D activities and later to organize its own laboratories where pure scientists produced by universities would do research useful to industry. That prescription can be faulted on two counts. The council had incompatible functions; it could not be expected to maintain its credibility as an impartial adviser on the R&D activities of other government departments and agencies when it was in competition with them for funds and staff. Moreover, the expectation that pure scientists in laboratories separated from industry would produce suitable research ignored the nature of the innovation process. As a result the National Research Council never really exercised its advisory function, research done in its laboratories was not used extensively by industry, and Canada remained a technological colony.[1]

The established Canadian model of the innovation process for decades derived from a linear relationship: "science discovers; technology applies." Detailed empirical studies of the innovation process in the

U.S.A. and Europe show that this model is oversimplified, describes few of the innovations that have been studied, and would only distort science policy decisions and hinder innovation if generally accepted. These innovation studies allow a better understanding of our lack of innovative success: the model put forward by Canadian science spokesmen has not worked anywhere else either.

In 1963, again, the diagnosis of the Glassco Commission was clear and well conceived. The basic need for a more effective central machinery for science policy was duly underlined. The commission's prescription was weaker in several respects, however, especially when it assigned the responsibility for reviewing government departments' R&D budgetary proposals to a council largely controlled by the top officials who had proposed the programs in the first place. As implemented after revisions by Dr. C. J. Mackenzie, it could not provide a strong or credible central machinery and again the initial objective was not achieved. The Science Secretariat and the Science Council did not significantly affect the decision-making process related to science policy issues.[2]

These mistakes of the past should not be forgotten when, as we hope, the government makes a third major attempt to organize its machinery for science policy. This time more attention should be given to prescription and implementation. In this chapter, the Committee presents its prescription for the kind of central machinery the Canadian government should develop and the role it ought to have. To put our views in perspective, it is important to consider first the present terms of reference of the Ministry of State for Science and Technology.

THE PRESENT ROLE OF THE MINISTRY OF STATE FOR SCIENCE AND TECHNOLOGY

In 1916 the Canadian government abandoned the pluralistic model and opted for co-ordination. Over the years, and more particularly in the 1960s, it sought to strengthen its advisory central machinery. Another important step in that direction came in June 1971, when it announced the creation of the Ministry of State for Science and Technology (MOSST).

It must be clearly recognized, however, that MOSST's role was conceived *within the framework of the co-ordination model.* While its creation has undoubtedly strengthened the central machinery for science policy, its main function is advisory. This was underlined by Mr. Drury when he described the responsibilities of the new minister:

> His policy-formulating roles will be characterized by activities such as advising, monitoring, forecasting and co-ordinating.[3]

The minister's terms of reference are reproduced as an appendix to this chapter and confirm Mr. Drury's interpretation. While the minister is expected to formulate policies for "the most appropriate means by which the Government of Canada may . . . have a beneficial influence on the application and development of science and technology in Canada," his main role appears to be to "*assist departments and agencies of the Government of Canada* in the formulation and development of advice to the Governor in Council. . . ." The Committee is of the opinion that the responsibilities of the new ministry are fundamentally the same as those assigned to the former Science Secretariat (the description is Dr. R. J. Uffen's):

> It is a service agency whose primary task is to *assist government departments and other agencies* in getting their proposals before the cabinet in an orderly manner and in such a way as to give the ministers the clearest picture of the problems under discussion and the options open to them [emphasis added].[4]

Thus, the organizational change of 1971 resulted mainly in enlarging the staff of the former Science Secretariat and transforming it into a ministry reporting to its own full-time minister rather than to the Prime Minister. If we accept the claim made before the Committee by a former science adviser to the U.S. President that his job corresponded in practice to a cabinet post, we find a great similarity between the present Canadian central machinery for science policy and the arrangement recently disbanded in the United States. The Minister of State for Science and Technology has responsibilities similar to those the science adviser to the President had. The ministry itself has terms of reference closely resembling those of the former U.S. Office of Science and Technology. The President's Science Advisory Committee had a role with important similarities to that of the Science Council of Canada. The Federal Council for Science and Technology corresponded to the Advisory Panel for Scientific Policy in Canada.

The Canadian government had an excellent objective in mind when it created the new ministry. As Mr. Drury put it, "It is our intention to utilize science and technology still more effectively in carrying out all of the functions of government."[5] But we fear that once again the prescription will fall short of the goal it is supposed to achieve. Conceived mainly as a service agency to assist departments and agencies that remain free to accept or reject that assistance, the ministry has been placed on a sideroad, like the Office of Science and Technology in the United States, and its role in the decision-making process can only be marginal. Sooner or later MOSST will face a dead end unless it is given more authority.

In our view, developing the strength of the central machinery for science policy should now have serious attention. Fortunately the government showed no evidence of moving in a backward direction in 1971,

but instead viewed the strengthening of the machinery as a gradual process. This we believe to be realistic. Indeed, Mr. Drury stated:

> There is an ancient Chinese saying: "A journey of one thousand miles begins with the first step." . . . the Government believes the creation of the ministry of state for science and technology and the appointment of the minister of state constitute that necessary first step.[6]

As the next step, another variation of the advisory role of the ministry could be envisaged. Instead of being a service agency to government departments and agencies it could become Treasury Board's adviser on government scientific activities. Departments and agencies would continue to present their estimates to Treasury Board, but the board would submit the proposed R&D programs to MOSST for advice before proceeding to its own review of the estimates. The minister could be a member of the board or act as an outside adviser.

It is possible, as some have proposed, for the minister to be an outside adviser and not a member of the board. The Committee finds this plan awkward for several reasons. At best, it is an attempt to put the ministry in the decision-making process through the back door. It might be argued that if the minister acts as an outside adviser he would be freer to make his own assessment and would have a greater influence on the board's decisions. We find this argument unrealistic. We do not see how the minister's freedom to assess R&D programs could be reduced by his being a member of Treasury Board. Within our system of ministerial responsibility, ministers are always free to present their own views, though they cannot escape cabinet solidarity once a collective decision has been reached. We also fail to understand how the minister could have more influence on the board's decisions as an outside adviser. To be consistent with this reasoning, one would have to argue that a minister would have a greater impact on government policies if he were not in the Cabinet.

It is obvious to us that the Minister of State for Science and Technology should be a member of Treasury Board in order to give advice directly to the cabinet members involved and to defend the ministry's views against those of departments and agencies. However, whether or not the minister is a member of the board does not alter the deficiencies of the basic mechanism, under which the minister and ministry staff would present a detailed appraisal of the R&D programs while the board would keep its responsibility for detailed approval of the programs. The Committee does not favour this approach because it would make the minister simply an adjunct and adviser to the President of Treasury Board. This relationship is incompatible with our system of ministerial responsibility.

MOSST could play a meaningful decision-making role if the board were to accept its advice automatically. But then the board would have

given up its specific responsibility and become, for all practical purposes, the rubber stamp of the ministry—an unlikely role for any agency.

It is more likely that Treasury Board would decide to discharge its obligation in a fully responsible manner, which would mean it would have to review and re-assess the assessment submitted by the ministry. To do this it would have to employ its own science advisers and seek the reaction of departments and agencies to the ministry's assessment. The whole review process would then start all over again, merely adding another link to an already long and frustrating decision-making process. In effect there would be two treasury boards for science and technology, one advisory, the other with authority. Under such conditions, the ministry would soon look like a futile nuisance to everyone involved.

But the Committee would like to point out again that Treasury Board is not the ideal agency to make the detailed review and assessment that are needed in the area of science and technology. It is already fully occupied with the general supervision of the whole expenditure budget and personnel management. Its members are selected on a regional basis and are not necessarily equipped or interested enough to deal efficiently with detailed and complex matters related to science and technology. According to Mr. Drury, "The Treasury Board in the past has not been much of a generator of new policies or new ideas: it is rather more co-ordinator and controller than it is a generator." Furthermore, what we said in Chapter 19 about the U.S. Office of Management and Budget applies equally to Treasury Board: it is not the right place for the widely diverse specialists in science and engineering required, nor could it hope to attract scientists and engineers of the highest calibre. A treasury organization is not set up to provide a stimulating environment for developing new technological opportunities or to build a capacity to evaluate scientific or technological issues in detail.

We are satisfied the government took the right decision in establishing the new ministry as it did, but only as a "necessary first step." It was wise to give the new organization time to start to walk and become stronger; to develop leadership, to learn how to formulate and develop policies, to acquire administrative experience. Indeed many of the recommendations directed toward the ministry in Volume 2 had this in mind.

However, this period should now be brought to an end before resentment from outside and frustration from within develop to the point where a setback will nullify "the necessary first step." The government has gone as far as it could with its co-ordination approach and must realize that the new ministry will not be able to survive for long as a useful central machinery for science policy if its main mission is limited to advising and assisting other departments and agencies or Treasury Board. Co-ordination is not "a dirty word," as the late Dr. Steacie once called it, but without authority and effective control it is an empty word.

As the Committee has shown before, operating departments and agencies have an understandable inclination to accomplish their R&D missions unaided by others, to seek self-sufficiency in their own range of activities, and to be defensive rather than self-critical. They already resent what supervision and control Treasury Board is able to exert. When they see another outside agency trying to "assist" them and realize they have the right to refuse assistance, they are likely to exercise it.

The Treasury Board is likely to look at the central advisory machinery for science and technology as an intruder competing with its own function, which, according to a deputy secretary of the board, is to "propose to the Cabinet as a whole how the Government should allocate funds among competing programs."[7] Again, such an attitude constitutes a normal reaction; an understandable but not desirable one.

Faced with this inimical environment, the central advisory machinery is bound to become more timid in its initiatives, to think twice before offering assistance that is not wanted, and to become frustrated and demoralized. As this process goes on, the organization is likely to lose its best people and fail to attract able replacements, so that the quality of its services will decay. Treasury Board and other departments and agencies will then be in a position to show that advisory central services are useless, and the advisory organization will retire within itself or seek other missions as an evasion and in order to survive.

The process will be completed and the government will be back where it started. The Treasury will be left as the only supervising and controlling agency, but as William Carey pointed out, it "has to have confidence in the quality and responsibility of planning and project selection at the level of the supporting agencies."[8] When Simon Reisman was secretary of Treasury Board, he expressed a similar view in his statement to the Committee that individual departments and agencies should be left with the responsibility of determining their science policies within the financial constraints imposed by general budgetary considerations.

Thus we conclude that the present central machinery does not represent a major improvement over the pluralistic model and is not conducive to a "rational science policy." Since this expression has been criticized, it appears necessary to define what we mean by the term "rational." Some commentators believe a rational science policy can only be derived by an inductive process when all factors affecting science, technology, and innovation are fully known and understood. This is a fantasy nurtured chiefly among academics, some of whom have chided the Committee for its "unscientific" approach toward the development of a rational science policy. However, one skilled academic observer of science policy, Stephen Toulmin, has not fallen into the trap, and we commend his definition:

> There is no such thing as an "intrinsically rational" concept in science, and there is no such thing in technology (or law) as an "intrinsically rational" engineering

> design (or legal procedure) either. What is "rational" is the judgement that, of the available novelties, some given design, or procedure, is superior to existing ones in a sufficient range and/or combination of respects to be worth adopting; and this does not imply either that it is the only "rational" procedure possible, or that it is the best which could coherently be conceived. . . . Neither the rationality of theoretical concepts nor the rationality of practical procedures can be judged definitely, timelessly, or once-for-all. . . . The rationality of collective human enterprises being what it is, this means always the Better-for-the-Time-Being.[9]

In this context, we believe that "the Better-for-the-Time-Being" does not consist of going back to the jungle of the past, when government departments and agencies were free to initiate their R&D programs in independence and isolation. We are equally convinced that it would be "irrational" to expect effective co-ordination of science activities from a purely advisory central machinery. Toulmin asserts: "The hindrances to rationality, too, are the same in technology as in science: e.g. institutional conservatism, the interests of dominant individuals, reckless or over-cautious management, and excessive rivalry between professional generations."[10] These hindrances cannot be overcome by mere advice and assistance from the centre.

A NEW ROLE FOR THE MINISTRY OF STATE FOR SCIENCE AND TECHNOLOGY

The Committee hopes that Mr. Drury's first step will in fact become the last step in the application of the co-ordination model based on an advisory central machinery. Basically, a new model is needed. The government must develop a new philosophy of organization and a more meaningful role for the Ministry of State for Science and Technology.

The time has come to face the situation frankly and realistically. There are only two options. Either government expenditures devoted to science and technology raise specific problems of planning and control requiring a special review and assessment procedure or they do not, in which case they should be treated like other government expenditures. Either the minister and ministry personnel become, for the purpose of the science budget, the focus of a concerted planning and control procedure with responsibilities similar to those of the President of Treasury Board and his staff or the ministry should be abolished. Either the government goes back to the pluralistic model or it adopts the concerted action model. Any attempt to find a compromise between these two alternatives is bound to be cumbersome, futile, and frustrating. This is the only conclusion we can draw from the Canadian experience since 1916 and from recent developments in other countries.

People who propose the hybrid solutions reviewed above are inconsistent. They recognize that government expenditures on science and tech-

nology create a specific problem of planning and control but they are not prepared to alter the present budgetary procedure to any significant extent, except by making it more inefficient and roundabout. They object to a special assessment and control process and refuse the concept of an *explicit* science budget on the ground that expenditures devoted to research and development cannot properly be considered apart from the operations of departments and agencies. And yet, when they favour a central machinery to advise these departments and agencies or Treasury Board on all significant government R&D activities, they accept *implicitly* that the concept of a science budget is meaningful and susceptible of an independent and separate assessment.

The Committee believes that the Ministry of State for Science and Technology should become the focus of a central machinery for the concerted planning and control of government involvement in science and technology. It already has a significant role to play in the formulation of policies "by which the government of Canada may . . . have a beneficial influence on the application and development of science and technology in Canada."

In this capacity it has taken the initiative in several fields, such as the "make or buy" policy, which is expected to improve the position of the private sector as a performer of R&D and as a source of successful innovations. This function will become even more important as it is extended to include the positive assessment of technology and the detection of new opportunities that are not being adequately explored by individual departments and agencies. Related to these missions is the responsibility for continually reviewing the government organization designed to deal with science policy matters. We understand the ministry is taking an active interest in this area.

We are convinced, however, that MOSST will be more and more inhibited in its policy formulating function by its role as a service agency designed to assist departments and agencies. These two missions are, to a large extent, inconsistent and can only lead to administrative confusion. How can the ministry decide that in certain cases it may take the initiative to formulate new policies and that in other policy areas it must merely assist departments and agencies? To remove this inconsistency and confusion, to reinforce the policy function of MOSST, and to ensure a general but real oversight of the government involvement in science and technology, the ministry must have the responsibility for reviewing and assessing the annual estimates and five-year forecasts which should be included in the science budget.

The new procedure would involve the following steps:

1. Departments and agencies would continue to prepare their budgetary proposals as they do now, except that they would separate

their scientific activities from their operational programs. This would not mean a significant departure from present practice, because departments and agencies already have to isolate their scientific activities at a later stage to report them to Statistics Canada. Putting them in a separate package while they are still in the form of proposals or estimates would bring the obvious advantage of enabling heads of departments and agencies to look at their scientific programs more closely and to exercise more effective scrutiny and control *before* they decided to continue current activities or initiate new programs. (The Committee was told that its hearings had induced certain departments to take their first serious look at their scientific activities.)

2. The science budget or the estimates related to scientific activities prepared by departments and agencies would be submitted to the Ministry of State for Science and Technology for review and assessment, instead of being presented to the staff of Treasury Board. For the government as a whole and for Treasury Board in particular, this procedure would represent a significant improvement over the present situation. Supervision by an impartial group of science policy advisers would offer a better guarantee that waste and undesirable duplication were minimized and that new opportunities were not missed. For heads of departments and agencies, who are often too busy with their operational programs and not adequately trained in evaluating scientific activities, the proposed procedure would provide a safeguard and a protection. They would know that their own appraisal of a specialized area to which they could not devote much of their time would be checked by skilled people whose only interest would be in maximizing the value of the R&D input to the policy objectives of their department or agency. For competent and motivated scientists and engineers in government establishments, the new system would guarantee a fair hearing, which would naturally give preference to promising programs and projects over those with a lower priority.

3. Once the science budget of individual departments and agencies had been reviewed and assessed by MOSST, it would be submitted for approval to an interministerial committee presided over by the Minister of State for Science and Technology. The President of Treasury Board would be an *ex officio* member and its other members should be ministers responsible for important science budgets. This would give the ministers the opportunity to become better acquainted with the scientific activities for which they are directly responsible and see them in the perspective of the overall government involvement with science and technology, and would undoubtedly lead to a significant improvement in the contribution

of science to policy. In the course of its examination, the committee would determine the overall government science budget, including the R&D envelope.

4. The science budget approved by the interministerial committee would be presented as a package, or as if it were the estimates of an ordinary department, for Treasury Board's consideration. If the board were to find the science budget was too high in the light of the overall government priorities and budgetary constraints, it would be expected to use its "pair of scissors" as it can for the estimates of an ordinary department. If the Minister of State for Science and Technology, who should be an *ex-officio* member of the board, were to disagree with the board's decision, he should have the right, in his capacity as chairman of the interministerial committee, to appeal before the full Cabinet.
5. If the final decision was to cut the science budget, it would be the responsibility of the interministerial committee to determine how and where the cuts should be made. The advice of MOSST and its overall knowledge of government priorities and programs in science and technology would put the committee in a better position than individual departments and agencies or Treasury Board to cut the least desirable programs.
6. The approved estimates of departments and agencies consolidated in the overall science budget would be published separately, as is now done in some countries. This would give Parliament and the public a better idea than they now have of the size and distribution of the government's scientific activities.

This procedure is not as revolutionary as it may appear. On the one hand, it would not reduce Treasury Board's normal control over the whole expenditure budget under the planning, programming, and budgeting system, which leaves departments and agencies the freedom to determine their priorities within the constraints of general budgetary considerations. On the other hand, it would give MOSST an effective leverage to supervise and assess the formulation and execution of sectoral science policies and give it general oversight of scientific activities, thus ensuring the macroscopic view needed to complement the microscopic approach that departments and agencies have to take.

This review procedure that we propose rests on the explicit recognition of a visible science budget. The operational definition and the determination of the budget's content should not present serious difficulties. At the beginning of the committee's hearings it was noted that some departments and agencies were not too careful in the preparation of statistics

on their scientific activities. The then Dominion Statistician observed that the figures presented to the Committee differed substantially from those received by DBS from the same sources. There were problems of definition and interpretation.

Since then, however, anomalies and gaps have been eliminated. We should like to think this great improvement was a by-product of our inquiry. The Committee appreciates the work done by Statistics Canada and the Interdepartmental Committee on Scientific Expenditures and congratulates the Ministry of State for Science and Technology for the annual publication of its Green Book, *Scientific Activities*. Because of this collective effort the government is now in possession of reliable statistics on its scientific activities, including the human sciences.

To illustrate the general scope and size of the science budget that would be submitted for review we reproduce two tables showing total expenditures on scientific activities by department or agency for the fiscal year 1972-73 in the natural sciences and human sciences. (Scientific activities are defined to include research and development, scientific data collection, scientific information, testing and standardization, feasibility studies, and scholarship programs; engineering is subsumed under "natural sciences.")

These two tables detail a science budget totalling $1,082 million which would have been submitted to the special review procedure we propose. The amount is small by comparison with the overall government expenditure program, and the R&D portion is about the same as the R&D expenditures of the Bell Telephone Laboratories in the United States. That is why we believe the special review and assessment of the science budget would not require a large staff. Here, as in many other areas, quality is preferable to quantity.

The Committee is convinced that the proposed review procedure is all the more necessary precisely because the science budget of the Canadian government is small. As MOSST's terms of reference assert, "science and technology vitally affects the well-being of Canadians and the future of Canadian society as a whole." To derive maximum returns from a rather limited investment, it is essential that the government give special attention to this vital area.

Accordingly, it is our deep conviction that the terms of reference of the Ministry of State for Science and Technology should be modified to enable it to assess the science budget by the special procedure we have described. We believe that a small but meaningful change in the penultimate section of its mandate would accomplish the purpose. At present, the minister is expected to "*assist* departments and agencies of the Government of Canada in the formulation and development of advice to the Governor in Council. . . ." This wording should be changed to require the minister to "*review and assess* the formulation and develop-

ment of advice by departments and agencies of the Government of Canada to the Governor in Council. . . ."

Table 25—Total Expenditures on Scientific Activities in the "Human Sciences" by Federal Department or Agency for 1972-73 (Millions of dollars)

Department or Agency	Total (Millions of dollars)
Statistics Canada	65.454
Canada Council	20.323
Indian and Northern Affairs	16.582
Urban Affairs	13.310
Regional and Economic Expansion	7.965
Manpower and Immigration	6.247
National Health and Welfare	6.166
Environment	5.870
National Library	5.380
International Development Research Centre	4.300
Science and Technology	4.102
Treasury Board	3.560
Privy Council	3.300
Others	39.181
TOTAL	201.740

SOURCE: *Scientific Activities*, Federal Government Costs and Expenditures 1963-64 to 1972-73, Ministry of State, Science and Technology, September, 1972, Chart 13.

Table 26—Total Expenditures on Scientific Activities in the "Natural Sciences" by Federal Department or Agency for 1972-73 (Millions of dollars)

Department or Agency	Total (Millions of dollars)
Environment	204.580
National Research Council	143.320
Industry, Trade & Commerce	100.422
National Defence	87.447
Agriculture	69.867
Atomic Energy of Canada Ltd	68.087
Energy, Mines & Resources	59.794
Medical Research Council	38.000
National Health & Welfare	29.556
Communications	23.778
Canadian International Development Agency	13.650
Atomic Energy Control Board	7.610
Consumer & Corporate Affairs	7.001
Transport	5.772
Others	21.647
TOTAL	880.531*

SOURCE: *Scientific Activities*, Federal Government Costs and Expenditures 1963-64 to 1972-73, Ministry of State, Science and Technology, September, 1972, Tables 1 and 3.

*61% conducted intramurally.

The Committee, therefore, recommends that the penultimate section of the terms of reference of the Minister of State for Science and Technology be changed to read as follows:

> **His Excellency in Council is further pleased to specify that the Minister of State for Science and Technology shall, in relation to the formulation and development of the aforementioned policies, have such duties as may be assigned to him by law, and without limiting the generality of the foregoing, shall review and assess the formulation and development of advice by departments and agencies of the Government of Canada to the Governor in Council with regard to**
>
> **(a) the optimum investment in, and application of science and technology in pursuit of national objectives,**
>
> **(b) the organization of the scientific establishment in the public service of Canada,**
>
> **(c) the allocation of financial, personnel and other resources to Canadian scientific endeavours, and**
>
> **(d) the extent and nature of Canada's participation in international scientific activities and the co-ordination of related domestic activities.**

We interpret the word "scientific" in these paragraphs to cover both science and technology. The change proposed in the terms of reference would not require any legislative action, yet it would give the ministry a significant responsibility in the last phase of the decision-making process instead of a mere assistance function at the beginning of that process. The ministry would be changed from an easily ignored service agency to the focus of an overall supervision and control machinery that could not be by-passed. The new review and assessment function would also significantly reinforce the ministry's present policy formulation mission and enable it to provide real and positive leadership to the whole government establishment in science and technology.

In this new role as the focus of the central machinery for concerted action, the ministry would, of course, be entitled to carry out or contract out research directly related to its responsibilities but it should not be responsible for *any* departmental or agency scientific program, *not even for the budget of granting institutions*. The Committee feels very strongly that this is an essential requirement if MOSST is to preserve its impartiality, its objectivity, and its credibility. This was the conflict that prevented NRC from effectively exercising its advisory role; it must be avoided in the future.

The Ministry should be required, however, to take a positive and active attitude in its assessment of new scientific activities and its continuing review of approved programs. It should not hesitate to suggest cuts where reductions seem appropriate, but it should also be prepared to

propose increases when departments and agencies appear to neglect their scientific effort. It should devote particular attention to grey areas, where multi-departmental programs are involved. These are just the areas that are most likely to be neglected because they do not belong to the main mission of any department or agency. The ministry should take the initiative in proposing special inter-departmental activities or, if this does not appear appropriate, new agencies to fill the gaps.

The ministry would also have to consider the redeployment or the closing down of existing organizations that have accomplished their mission or become obsolete. This difficult problem was discussed at the 1971 CIBA-funded *Symposium on Civilization and Science.* In discussion there, Alvin Weinberg stated:

> The obsolescence of large scientific institutions worries the scientific community in general and nuclear scientists in particular. Of course these institutions have a natural imperative to survive, as does any bureaucratic organization. . . . This problem of the obsolescence of large institutions is in some sense one of the central structural problems of the scientific community, and it therefore affects the relations between science and society. . . . But actual redevelopment requires one to propose very definite things to do, not vague generalities.[11]

In the discussion, Lord Todd said:

> The permanent staffing of research institutions is where we make a big mistake. Redeployment is bad enough under any circumstances, but the permanent staffing of research institutions has given rise to much trouble. Finding big new tasks is a tremendous problem. One is starting at the wrong end: instead of finding something that one can work on, one is starting out with a set of facilities and people and trying to find a problem to match. Unless continually changing economic objectives can be found, research institutions die. The only way to carry on without economic objectives is in a university, where the reason for doing research is to train young people who keep moving on after a year or two and are continulally replaced by new young workers.[12]

Christopher Freeman, head of the Science Policy Study Unit of the University of Sussex, commented:

> In this whole question of redeployment of government laboratories it is essential to bear in mind the experience of industry in making innovations. Innovation only succeeds where a need, a requirement of society, is clearly recognized. Simply to say 'Let's do environmental research' is quite insufficient. One needs to have a very clearly defined goal and . . . just can't get going on a vague and ill-defined objective.[13]

Freeman went on to point out that quite often there is a temptation for institutions, in attempting to redeploy, to simply duplicate R&D activities that have already been concluded in other organizations.

The Committee suggested earlier that the minister should be an *ex-officio* member of Treasury Board and should also have a place *ex officio*

in the Cabinet Committee on Priorities and Planning. The minister's present terms of reference justify participation in that committee when they state that "science and technology vitally affects the well-being of Canadians and the future of Canadian society as a whole," that the minister "shall formulate and develop policies with respect to . . . the co-ordination of programs and activities regarding science and technology with other policies and programs of the Government of Canada," and that the Minister may undertake policy studies "to further knowledge and understanding of the impact of science and technology on society." With that mandate the minister is certainly in a position to make a most useful contribution to the Cabinet Committee on Priorities and Planning.

The Committee therefore recommends that the Minister of State for Science and Technology be an ex officio member of Treasury Board and of the Cabinet Committee on Priorities and Planning.

We believe that the ministry, as the focus of the central machinery for concerted action in science and technology programs, would constitute a most effective and valuable type of organization. But to function properly a good organization must also find good people, including competent and dedicated administrators.

The central science policy machinery is as dependent on the authority implicit in the ministry's staff skills as it is on the statutory authority granted to it. This point may be illustrated from experience in the United States where recently the science journalist Claude E. Barfield has collected some comments on the effectiveness of OST.[14] Several White House and Domestic Council members said "they had not found OST advice of unique utility or packaged in a way they found helpful." Barfield quotes William E. Kriegsman, a former Domestic Council staff member, as saying that "DuBridge was a sweet guy with impeccable credentials and a desire to help; but when we asked OST for advice, they kept coming up with answers that weren't usable or which didn't fit the political realities. The White House staff had to handle most of this work itself. . . ." A current Domestic Council staff member is quoted as saying that the OST "were no more right on a number of issues than other agencies. . . . They didn't constitute the most important opinion-analyzing source for us." A White House staff member who conducted management studies of OST in 1972 "found that in the areas of coordination, policy planning and management of the federal R and D program, OST had not contributed a great deal." These views that Barfield collected show the necessity of basing authority on sufficient skilled staff of the appropriate kind.

The criteria for the selection of staff should be determined by the mission of the organization. As we see it, the ministry should have two

main roles: a policy formulation function to provide leadership, and a management responsibility for the organization of the government involvement in science and technology and for the review and assessment of departments' and agencies' scientific programs.

On that basis, the ministry should be staffed mainly by science policy advisers and science and technology managers. The temptation to hire scientists and engineers with no experience in policy formulation or management should be resisted. Expertise in science and technology as such is clearly needed but it should come mainly through outside consultants hired on a contractual basis for specific assignments.

When a scientist or a technologist has been engaged in R&D activities for many years, he has usually become highly specialized in certain specific areas as a supplier of research services. He may be well qualified to generate new ideas in his own discipline or willing to respond enthusiastically to the challenges of an R&D program. A research manager, however, must have other skills, or develop them. He must appraise programs and, to do so, he must be able to apply proper evaluative techniques. In other words, he must be primarily a good manager rather than a researcher. These qualifications and skills would be more necessary with the ministry's new terms of reference, which would require a concentration on the assessment of demand-pull rather than supply-push R&D.

The Committee is under the impression that MOSST has been built up to give scientific advice rather than to provide science policy or science management services or to conduct evaluations. This is probably what it was expected to do when it was set up. However, if it is to develop along the lines we have suggested, it may have to revise its structure and hence its recruitment policy. In terms of its structure and its monitoring techniques, it should look closely at the organization of Treasury Board and use it as a model wherever it is compatible with its own particular mission. It should recruit more social scientists interested in science policy and more management specialists interested in research, development, and innovation.

The terms of reference specify that the minister may "determine and promote the use of methods for assessing the effectiveness of scientific policies and programs." The Committee hopes that this particular authorization will be given high priority. We stressed this point in Volume 2 when we stated: "Research on research is the key to improving the formulation of science policy, developing better management techniques for R&D programs and personnel, and maximizing the overall scientific and technological output."[15] It is only by developing a strong, broadly based expertise in this area, and doing it as soon as possible that MOSST will be able to establish its credibility in its dual role of formulating

science policy and assessing the scientific programs of departments and agencies.

In view of the major change in responsibilities we propose for the ministry important modifications in its organization will be desirable. These should be the subject of a special review carried out, not by the staff of the ministry because of the internal difficulties such a procedure might create, but in close co-operation with it. Only an outside and impartial review will guarantee that the ministry will be properly organized and equipped to carry out its vital role.

The Committee, therefore, recommends that an outside task force be set up to review the organization and structure of the Ministry of State for Science and Technology and to make recommendations in this respect in the light of its proposed new mandate.

We suggest that this review should be made under the auspices of the Privy Council Office. It would be useful to have consultants from outside the public service who are specialized in management techniques and, more particularly, who have wide experience as research managers in the private sector. It would certainly be most desirable to consult with the staff of the General Delegation for Scientific and Technical Research in France. The Committee attaches great importance to this review. As we said before, a good prescription can be ruined by bad implementation. A good concept may be destroyed by bad design.

AN INTERMINISTERIAL COMMITTEE FOR SCIENCE AND TECHNOLOGY

We have proposed that the Minister of State for Science and Technology and his ministry should have the responsibility for formulating science policy and for reviewing and assessing the science budget. This would affect the policies and activities of many departments and agencies. But, in our system of government, a minister cannot be put in the position of assessing and controlling policies and activities that are the responsibility of others in the Cabinet. The ministry would have to seek the approval of a Cabinet committee for its recommendations and proposals whenever they affected the duties of other ministers. At present, it reports to the Committee on Science, Culture, and Information. We do not think this arrangement is appropriate to the important new responsibilities we have proposed for the ministry. Problems related to mission-oriented research, development, and innovation have little to do with culture and information.

The former Privy Council Committee on Scientific and Industrial Research created in 1916 never really worked. The National Research Council was supposed to advise it on science policy matters, but was too busy with its other functions and in a rather difficult position for fulfilling that role effectively. Few Cabinet committees have worked properly until recently, and, with the exception of the Treasury Board, they have often been ignored, specially by powerful ministers. The Committee on Scientific and Industrial Research was expected to restrict its attention to major new programs and to limit its considerations to their scientific merit. So partial a review could hardly be very meaningful to ministers preoccupied with their own departmental responsibilities and aware that the ultimate decision would be taken by Treasury Board, largely on the basis of financial considerations.

Decisions on the planning and control of science activities must be coherent to be meaningful. They must be based on a synthesis of considerations—political, financial, administrative, and scientific—that can hardly be separated and assigned to different committees. When those considerations are separated the financial aspect tends to predominate, which makes the scientific review look futile to busy ministers. Since the criteria that should help determine government support for science activities are practically indivisible and since these activities, according to the government, are of crucial importance for the future of the country, there is a real need for a special and powerful interministerial committee for science and technology.

Its role should reflect the terms of reference of the ministry in its dual responsibility for formulating policy in the area of science and technology and assessing the scientific programs of departments and agencies. But the interministerial committee would have the power *to approve* these policies and programs. In arriving at its decisions it would be assisted by the personnel of the Ministry of State for Science and Technology in the same way as the secretary of Treasury Board and his staff serve the board.

The committee would be expected to determine the general goals, priorities, and strategies of a federal policy for science and technology. It would prepare medium-term and long-term plans for the government support of a balanced and realistic Canadian R&D effort. It would give scientific and technological advice to the government in matters of national importance. In this respect, the committee would report its findings to the Cabinet or preferably to the Cabinet Committee on Priorities and Planning.

The committee would also examine and approve new scientific activities proposed by departments and agencies and review the development of their approved programs. In the course of this examination, it would set a science budget and keep the government's organizational structure

under constant review, so as to uncover the need for any new agencies, specially when they involved multi-disciplinary programs, or for the termination of obsolete agencies. It would submit the science budget as a package to Treasury Board for the purpose of reconciling it with the overall budgetary constraints of the government (though we expect the science budget would not be subjected to rapid or significant fluctuations).

The chairman of the committee ought to be the Minister of State for Science and Technology. In addition to the President of the Treasury Board, ministers with major science policy responsibilities would be its members. Meetings between officials jealously guarding their territory, without a strong and impartial central leadership, often lead to sterile confrontation between departments and agencies and between the microscopic and macroscopic views rather than the cross-fertilization so much needed in this area; but we believe the membership and responsibilities of this committee would normally lead to a fruitful interaction.

The Committee, therefore, recommends that an Interministerial Committee for Science and Technology be established, under the chairmanship of the Minister of State for Science and Technology, to examine and approve general and specific science policies and scientific programs of departments and agencies and that the Minister's officials serve as the secretariat of the committee.

We believe such a committee is an essential addition to the central machinery for concerted planning and control of government support for science and technology. It would have operationally meaningful terms of reference and a strong but impartial leadership so that it could work properly. It would be linked through a two-way process to the Cabinet Committee on Planning and Priorities and to Treasury Board, so that decisions on science and technology would be taken within the broad framework of government priorities and budgetary considerations. But this special assessment procedure would also contribute to a better overall system of planning and priorities and to an improved process for the allocation of financial resources. For the government as a whole, it would represent a more efficient decision-making arrangement in a vital area of policy; for departments and agencies, it would provide a more enlightened and positive assessment procedure than the present system.

THE SCIENCE COUNCIL OF CANADA

Most countries that have attempted to develop a coherent science policy have set up an advisory body to help in the process, though the roles and

composition of these councils are not identical. For instance, in France the Scientific Advisory Committee is directly involved in the decision-making process. The research package prepared by departments and reviewed by the General Delegation for Scientific and Technical Research is submitted to the advisory committee, which presents its own recommendations to the International Committee for Scientific and Technical Research. The twelve scientists who compose the "Comité des Sages" attend the meetings of the interministerial committee with ministers interested in scientific matters. Thus, they can have a strong influence on policy decisions. In a few countries, like Sweden and Finland, the council is presided over by the prime minister.

Usually, however, these advisory bodies share three features. First they assist the decision-making process by giving advice but are not part of it. Secondly, they are composed exclusively of outside experts. Thirdly, their advice is presented to the government on a confidential basis.

Canada has followed the general pattern with two exceptions. The government sector is represented on the Science Council. Moreover, the practice has been for the council to publish its reports and recommendations, based in most cases on special studies made by committees mixing outside experts and staff members.

The life of the Science Council has not been an easy one. At the beginning it had no staff of its own and had to rely on the Science Secretariat, which, like the council, was responsible for giving advice to the Prime Minister. When he appeared before the Committee, Dr. Solandt expressed several misgivings. The council had no full-time chairman and was reporting to the Prime Minister, who had "other preoccupations." There was, he said, "no use in the Science Council making representations, if nothing happens."[16] The council was not permitted to deal with social sciences problems, although its act authorized it to do so. The presence on the council of a large number of representatives of the government sector was undoubtedly another factor inhibiting it in arriving at specific recommendations and acting as an impartial adviser.

Some of these difficulties have since been removed. We know, however, that no effective way has been found to give the council "access to the decision-making powers of the government," as Dr. Solandt had hoped. In his final report as chairman, issued in June 1972, Dr. Solandt again expressed his frustration: "Testimony from other countries suggests that the council may even have acquired at least one of the attributes of a prophet, by being less honoured at home than abroad."[17]

The Committee has devoted a good deal of thought to the role and composition of the Science Council. We have come to the conclusion that it should not become part of the decision-making process like the Scientific Advisory Committee in France. Whether it is composed exclu-

sively of outside members or partly of government officials in charge of R&D programs, it should not be asked to review the government's science budget or make any recommendations on it to the proposed Interministerial Committee on Science and Technology. Outside members would not have the knowledge or time needed for a proper evaluation and government officials serving on the council would be placed in the conflicting position of having to appraise their own proposals. Moreover we believe the special review procedure we have proposed is already elaborate and time-consuming enough without adding another statutory level of assessment.

When he appeared before the Committee, Dr. Solandt said of the Science Council that "in the field of science policy, we are the major agency advising the government." But this was before the creation of the Ministry of State for Science and Technology. Since the ministry's present role is also mainly advisory, the government now finds itself with two science policy advisers: the Science Council giving public advice and MOSST giving private advice. We seriously wonder whether this will not give rise to conflicts and frustrations, particularly since the ministry has begun to develop links with private organizations representing the scientific community and to seek their advice. If this continues we believe the role of the council will become even more difficult and frustrating as it grows more remote from the decision-making process of the government. If MOSST were to keep its advisory function and continue to assist departments and agencies or Treasury Board, we would recommend that the Science Council be abolished; just as in Britain there is now no council giving overall science policy advice to government, the Advisory Board for the Research Councils having replaced the Council for Science Policy in the move to greater pluralism.

The government does not need two frustrated advisory bodies. The council's budget could be used by MOSST to strengthen the organization of the Canadian scientific community, which greatly needs it, and to commission from these stronger private scientific institutions the special studies it needs to advise the government. Such a formula has proved advantageous in several countries, notably in the United States.

The Committee can see a useful role for the council only within the framework of the strong central machinery for concerted planning and control that we have proposed. If the ministry is made responsible not only for policy but also for reviewing the science budget, then—but only then, we feel—there will be a need for an impartial outside critic of the whole decision-making procedure.

Within that framework the council could provide a valuable service. Its most important continuing functions, as Dr. Solandt pointed out, should be to look at "broad areas of expenditure in order to see that the trends

of expenditure are in the right direction," and to deal with "broad strategic goals."

The council should report to Parliament through the chairman of the Interministerial Committee for Science and Technology. But if the council is to fulfil its impartial role with credibility it must be as independent as possible of the government and seek to reflect the views of the scientific and engineering community. The OECD examiners made a comment that is apt:

> Our feeling, based on experience elsewhere, is that the functions of the Science Council at present fall between two stools. It is not part of the active machinery of government and, on the other hand, its members being appointed by the Prime Minister and its Secretariat supported by public funds, it does not have the complete independence of a learned society solely representing the views of the scientific community.[18]

To remove some of the difficulties initially faced by the Science Council, the government has used the Economic Council as a model. But it has gone only part way and, we believe, should now go further. This would involve several changes in the composition of the Science Council and the scope of its activities.

First, the practice of appointing public officials to the council should be abandoned and associate membership should be abolished. This would not mean that heads of government agencies should never be consulted, but they should not be put in the position of having to appraise or criticize government policy in public. It would be advantageous, however, to establish closer relations between the Science Council and the Economic Council and to this end each chairman should be invited to meetings of the other council as an observer. We believe such an arrangement to be necessary in order to avoid overlapping.

Secondly, the Economic Council of Canada Act provides that apart from the chairman and the two full-time directors "each of the other members of the Council shall be appointed after consultations with appropriate representative organizations." We believe a similar procedure would improve the representative character of the Science Council, make its independent status more evident, and give more authority to its advice and criticism. At the same time it should extend its network of consultation to comparable provincial institutions, universities, industry, and the scientific community as a whole, including their representative organizations. Cross-fertilization in this area is very important. The Canadian scientific and engineering community has not been accustomed to discussing science policy issues collectively and has lived too much in isolation. The Science Council could play a useful role as a catalyst by sponsoring seminars to promote participation at the grass-roots level. Everyone in the scientific community obviously should take an active

part in the development of science policy; not only is participation beneficial in itself, it would allow the council, which often has operated in a vacuum, to gather and synthesize the community's views, thus giving them a better chance of being heard at the top and affecting the orientation of the national scientific effort.

Thirdly, the matter of the administrative decision that prevents the Science Council from covering the social sciences. It has not always been possible for the council to respect that decision, and as it becomes more interested in R&D activities leading to economic and social innovations, the exclusion of the social sciences from its consideration will appear more and more unrealistic.

The government needs as much advice on its activities in the sector of the social sciences and humanities as in other scientific areas. It has been proposed that a separate council should be set up for that purpose, but that is unnecessary and undesirable. Broad policy questions that have to be faced in this area are essentially the same as those that arise in other scientific disciplines. All scientific endeavours compete for scarce financial resources.

As more multi-disciplinary programs are initiated, it will become increasingly difficult to draw boundaries between scientific areas, because they will be really interdependent. Many Canadian social scientists and humanists have expressed the view that the Science Council should cover their disciplines.

Fourthly, this extension of the council's role and other considerations would require further changes in its composition. Dr. Solandt told the Committee in 1969: "I do not think that there is any doubt whatever that . . . the council would operate better with a full-time chairman and probably with a full-time vice-chairman." The Committee agrees, and suggests that one of these two full-time officials should come from the physical sciences, the life sciences, or engineering and the other from the social sciences or the humanities. With such an arrangement, which would be similar to the structure of the Economic Council, the posts of executive director and deputy executive director should be abolished.

Fifthly, the council's act now provides for 25 members and four associate members chosen from the public service. We have already suggested that the practice of appointing government officials as members or associate members should be abandoned. We further propose that the number of members be increased to 30. This would provide room for adequate representation from the social sciences and humanities.

The composition of the council should, we believe, be inspired by these guidelines:

*One half of its membership should come from the academic sector, the other half from the private sector, including industry and the professions.

*The membership should be divided into three equal groups representing the physical sciences, the life sciences, and the social sciences and humanities; and where appropriate each group should include an adequate number of engineers.

*On a regional basis, four members should come from the Atlantic provinces, nine each from Quebec and Ontario, and eight from the Western provinces.

Although these proportions would make appointments to the council more difficult they reflect the mosaic character of the Canadian scientific and engineering community and so provide broad and balanced representation.

Finally, we believe the name of the council should be changed to the Science and Engineering Council. This would give a better indication of its composition and scope.

The Committee therefore recommends:

1. That the name of the Science Council of Canada be changed to the Science and Engineering Council of Canada;

2. That the council be composed of a full-time chairman and vice-chairman, one representing the physical sciences, the life sciences, and engineering, the other, the social sciences and the humanities, and of twenty-eight other members chosen from outside the Public Service of Canada;

3. That the ordinary members of the council be appointed after consultation with appropriate representative organizations, and on such a basis as to adequately represent the two main non-government R&D performance sectors, the main scientific and engineering disciplines including the social sciences and humanities, and the four broad regions of the country;

4. That the terms of reference of the council be interpreted as covering the social sciences and the humanities; and

5. That the council, in the exercise of its broad function as an impartial observer, adviser, and critic of the formulation and implementation of science policy, maintain close liaison with the representative organizations of the Canadian scientific and engineering community for the purpose of getting their considered views on the orientation and development of that policy.

The Committee believes this recommendation would strengthen the council's independence and give it a more effective leadership, stronger roots in the community, and more credibility at the top. It would also

extend its mandate to cover the whole spectrum of science and technology and thus clearly enable it to help develop a "second generation of science policy" aimed at improving the process of social innovations. Within the framework of a central machinery for concerted planning and control of science policy, it would then be in a better position to advise and assist the Ministry of State for Science and Technology and the proposed interministerial committee.

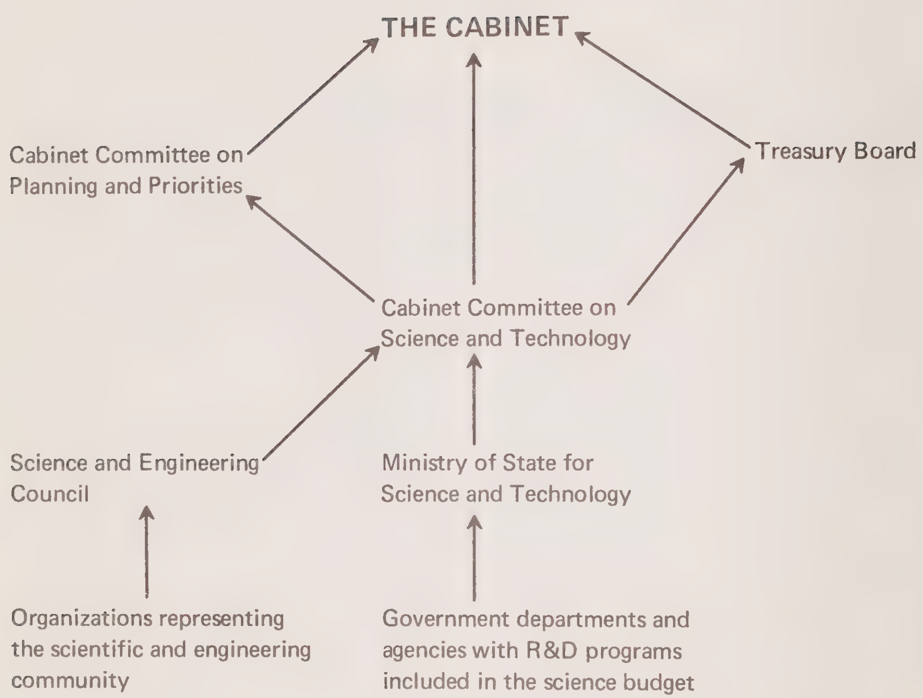
CONCLUSION

The Committee wants to reiterate its conviction that the Canadian government will never have a coherent and balanced science policy if it relies on a pluralistic model—that is, if it depends exclusively on individual departments and agencies to formulate and implement policy in isolation and as a mere sub-system of their missions. Experience in Canada and elsewhere has also clearly shown that various attempts to develop policy by using the co-ordination model and establishing a purely advisory central machinery to assist decision-making have failed; they have produced resentment and frustration and have soon proved to be a waste of public funds and energies.

The only realistic solution, the Committee believes, is to involve the central machinery directly and explicitly in the decision-making process without relieving departments and agencies of the responsibility for initiating proposals and operating programs. This means that the central organization must perform its review and assessment role *after* the departments have formulated specific proposals and *before* they implement the programs. This strategic role must be complemented by three other important functions: formulation of broad policy to facilitate the planning of new scientific activities; provision of initiative and leadership to help departments and agencies to respond quickly to new opportunities or threats; and continuing oversight over the implementation of approved programs.

We proposed to assign this important mission to the Interministerial Committee for Science and Technology, linked with the Cabinet Committee on Planning and Priorities and Treasury Board and assisted by the Ministry of State for Science and Technology with revised and more meaningful terms of reference. We want to emphasize again that, within this new framework, no government agency carrying out scientific activities and no granting institution should report directly to the ministry, for that would seriously impair its impartiality and credibility. A changed and strengthened body called the Science and Engineering Council would also be a valuable part of the proposed central machinery. Working

CHART 19


THE CABINET
Cabinet Committee on Planning and Priorities
Treasury Board
Cabinet Committee on Science and Technology
Science and Engineering Council
Ministry of State for Science and Technology
Organizations representing the scientific and engineering community
Government departments and agencies with R&D programs included in the science budget

closely with representative organizations of the scientific and engineering community, it would act as an outside observer, adviser, and critic of the whole decision-making process concerned with science and technology issues and of the broad orientation of science policy. Chart 19 represents the proposed line-up schematically.

The Committee regards these proposals related to a dynamic and meaningful central machinery for concerted planning as the most crucial set of recommendations of the report. We are firmly convinced that if the government fails to implement it, the science policy-making process will remain weak and erratic, with the result that science and technology will be unable to make their full contribution to the well-being of Canadians and to the future of our society. There will, of course, be bureaucratic opposition to the creation of an organization outside Treasury Board designed to deal meaningfully with issues of science policy, including their financial and manpower implications. We feel strongly, however, that the Canadian government has here an excellent opportunity to be bold, imaginative, and realistic.

The Committee believes that the implementation of these recommendations is urgent. Lacking a central focus with authority to make changes, government decisions on R&D will remain unco-ordinated and sporadic. The reorganization of departments and agencies involved in scientific activities may well be damaged or unduly delayed by what Stephen Toulmin called "the hindrances to rationality"[19] or what Donald A. Schon described as the "dynamic conservatism"[20] of institutions reluctant to modify their procedures or give up old responsibilities.

We feel the proposed central machinery could be easily set up. The creation of the Interministerial Committee on Science and Technology and the revision of MOSST's role would not require new legislation; nor would several of our proposals for making the Science Council a more effective observer of science policy—and others which would require amendments to the act could be implemented later. In any case no modification should be made in the role and composition of the Science Council until the government has reached a decision about creating the interministerial committee and the new mission of the ministry, because if it decides to preserve the status quo we would recommend that the council be abolished.

We hope, however, that our proposals will soon be implemented, for in our view they are the only sound prescription for the formulation and implementation of a "rational" science policy for Canada.

NOTES AND REFERENCES

1. The Senate Special Committee on Science Policy, *A Science Policy for Canada; A Critical Review: Past and Present,* Ottawa 1970, chapter 3.
2. *A Science Policy for Canada, op. cit.,* chapter 5.
3. House of Commons Hansard, June 21, 1971, p. 7166.
4. *A Science Policy . . ., op. cit.,* p. 100.
5. House of Commons Hansard, June 21, 1971, p. 7167.
6. Ibid.
7. D. G. Hartle, "Notes for Address to Medical Research Council Scholars", October, 1971, p. 2.
8. As quoted by William D. Carey in *Centralization of Federal Science Activities, op. cit.,* p. 69.
9. Stephen Toulmin, *Human Understanding,* Volume 1, Clarendon Press, Oxford, 1972, p. 371.
10. Ibid., pp. 370-371.
11. As quoted by H. Thiemann, "Science: a consequence of science policy or an expression of civilization?", *Civilization & Science,* A Ciba Foundation Symposium, published by Elsevier Associated Scientific Publisher, New York, 1972, pp. 84-85.
12. Ibid., p. 85.
13. Ibid., p. 86.
14. Claude E. Barfield, *op. cit.,* pp. 410-415.
15. *Targets and Strategies for the Seventies, op. cit.,* p. 381.
16. Proceedings of the Special Committee on Science Policy, Phase 1, 1967-1968, p. 43.
17. Science Council of Canada, Annual Report 1971-72, p. 54.
18. *Canada,* Reviews of National Science Policy, *op. cit.,* p. 412.
19. Toulmin, *op. cit.,* p. 370.
20. Social systems have a natural inclination to develop a resistance to change and an array of defence mechanisms leading to what Donald A. Schon calls "dynamic conservatism." See Chapter 2, *Beyond the Stable State,* Maurice Temple Smith Ltd., London, 1971.

APPENDIX

ORDER IN COUNCIL ESTABLISHING A MINISTRY OF STATE FOR SCIENCE AND TECHNOLOGY

WHEREAS science and technology vitally affects the well-being of Canadians and the future of Canadian society as a whole;

AND WHEREAS many of the policies and programs of the Government of Canada substantially influence directly and indirectly the development of science and technology in Canada;

AND WHEREAS the close cooperation of departments and agencies of the Government of Canada is required to ensure that the development and use of science and technology advances in a manner beneficial to all Canadians;

AND WHEREAS the need for policies directed towards the most effective use of science and technology in the achievement of Canada's national goals has become increasingly urgent;

AND WHEREAS it appears to the Governor in Council that the requirements for formulating and developing such policies warrant the establishment of a special portion of the public service presided over by a minister charged with that responsibility.

NOW THEREFORE His Excellency, the Governor General in Council, on the recommendation of the Prime Minister, pursuant to sections 14 and 15 of the Ministries and Ministers of State Act, is pleased to direct that a proclamation do issue establishing a Ministry of State for the purpose of formulating and developing policies in relation to the activities of the Government of Canada that affect the development and application of science and technology, to be known as the Ministry of State for Science and Technology and to be presided over by a Minister of State to be known as the Minister of State for Science and Technology.

HIS EXCELLENCY IN COUNCIL is further pleased to specify that the Minister of State for Science and Technology shall formulate and develop policies with respect to

(a) the most appropriate means by which the Government of Canada may, through measures within its fields of jurisdiction, have a beneficial influence on the application and development of science and technology in Canada,

(b) the co-ordination of programs and activities regarding science and technology with other policies and programs of the Government of Canada, and

(c) the fostering of cooperative relationships with respect to science and technology with the provinces, with public and private organizations, and with other nations.

HIS EXCELLENCY IN COUNCIL is further pleased to specify that the Minister of State for Science and Technology shall, in relation to the formulation and development of the aforementioned policies, have such duties as may be assigned to him by law, and without limiting the generality of the foregoing, shall assist departments and agencies of the Government of Canada in the formulation and development of advice to the Governor in Council with regard to

(a) the optimum investment in, and application of, science and technology in pursuit of national objectives,

(b) the organization of the scientific establishment in the public service of Canada,

(c) the allocation of financial, personnel and other resources to Canadian scientific endeavours, and

(d) the extent and nature of Canada's participation in international scientific activities and the co-ordination of related domestic activities.

HIS EXCELLENCY IN COUNCIL is further pleased to specify that the Minister of State for Science and Technology may

(a) initiate and undertake such research, analysis and policy studies as may be required to further knowledge and understanding of the impact of science and technology on society, and

(b) determine and promote the use of methods for assessing the effectiveness of scientific policies and programs.

SOURCE: House of Commons Debates, June 21, 1971, p. 7207.

21

REORGANIZATION OF DEPARTMENTS AND AGENCIES

In reorganizing the institutions and methods used to formulate and implement science policy the government should not restrict itself to establishing a central overview machinery. Within the framework of the concerted action model, individual departments and agencies have an important role of initiation and execution to play. They must develop and share the decision making.

The Rothschild report was largely devoted to the latter problem as it is raised by applied research and development. It is "based on the principle that applied R&D, that is R&D with a practical application as its objective, must be done on a customer-contractor basis. The customer says what he wants; the contractor does it (if he can); and the customer pays. Basic, fundamental or pure research, called basic research in this report, has no analogous customer-contractor basis. . . ."[1]

According to Lord Rothschild, the customer or the head of a mission-oriented department or agency should decide, "with advice or on his own initiative, that an R&D program is needed to achieve a specific objective" and "how much can be spent on the program," and "then determine priorities between programs." To fulfill these responsibilities, the customer normally needs the advice of a chief scientist. Each department and agency should also have a controller of R&D to act as "the chief executive of the R&D function. . . ." He should be, "*inter alia*, a specialist on program costs and the relationship between them and estimated completion dates." He should, of course, have the authority to commission work from extramural organizations.

The Committee strongly endorses this type of relationship. During our hearings we often observed the inverse relation. Even in mission-oriented

departments and agencies, R&D programs were supply-push rather than demand-pull. Scientists and engineers were expected to define their own projects and submit them for approval to directors of individual research establishments. In this way the supply of research services was the main determinant of the demand.

We do not think this is a satisfactory situation. We agree with the Rothschild report:

> However distinguished, intelligent and practical scientists may be, they cannot be so well qualified to decide what the needs of the nation are, and their priorities, as those responsible for ensuring that those needs are met. This is why applied R&D must have a customer. . . .[2]

And this customer, assisted by a chief scientist, must play an active role in determining the R&D program of his department and agency rather than adopt the purely passive attitude of accepting or rejecting proposals made by researchers.

The Committee recommends therefore that individual departments and agencies implement the principle, put forward in the Rothschild report, that applied research and development be done on a customer-contractor basis in order to improve micro decisions regarding science and technology.

The Ministry of State for Science and Technology should be assigned the responsibility of making sure that this recommendation is properly implemented wherever it should be applied. In many instances the customer-contractor relationship would reverse the present situation and ensure that the scientific activities of departments and agencies correspond to a real need rather than to the individual priorities of researchers. It would facilitate the application of the "make-or-buy policy." It should still allow, however, for the participation of researchers in the elaboration of R&D programs. For this reason, the chief scientist and the controller of R&D should work closely together.

The reorganization plan should also include new roles for some existing departments and agencies and the creation of new institutions to accomplish particular missions. Most of our proposals on these points were presented in Volume 2. The Committee feels, however, that it is useful to reconsider them in the light of the comments and criticisms made by the scientific and engineering communities. We do not refer specifically to each brief presented to us because that would involve too much repetition. We believe, however, that the comments we do refer to are typical of the reactions we have received.

On the whole, the spirit of our proposals for organizational change has been widely accepted. With a few important exceptions, the reservations expressed arise from misunderstandings caused by the conciseness of the Committee's recommendations or by concern over various operational

problems of implementation. Moreover, the organizations that made comments often interpreted our recommendations out of context, without taking sufficient account of supporting evidence.

Some of our critics have been criticized in turn. For example, a press conference was held at NRC headquarters in November 1972 to publicize a report on our Volume 2 prepared by NRC's Advisory Committee on Biology. Jeff Carruthers, the science writer, describes the report:[3]

> It over-simplifies, it distorts, and it sensationalizes. It makes comments about social science without any real basis of knowledge. ... Submitted as an introduction to a thesis in a social science, the advisory committee report would have been thrown out as immature, confusing, and unscientific, containing so many biased and inconsistent statements in only seven pages.

Carruthers goes on:

> The NRC should be severely chastised for allowing such a report to be promoted on its premises, let alone setting up the news conference. ... Obviously some scientists have a lot to learn about science policy and about accurate communication of science policy ideas—a lot more to learn than the Lamontagne committee senators the scientists seem so anxious to criticize.[4]

The Committee takes no solace from this incident because it shows to what low level the ability to communicate can sink. The seriousness of this is all the more apparent when it is realized that among those signing the report were scientists of notable skill and important public responsibilities. This situation gives as graphic an illustration as one could require of the importance of improving the quality and responsibility of communications between the people concerned with science policy. And it demonstrates that a knowledge of science and a knowledge of science policy are not the same thing.

THE RELATION BETWEEN BASIC RESEARCH AND INNOVATION

The role of basic research in the innovation process is one of the major determinants of a rational government organization for science and technology. We have come to the conclusion that disagreement about the nature of that role as perceived by us and our critics was the main source of opposition to several of our specific proposals for reorganization. Because of its important practical implications we believe it is essential to return to this topic.

Nothing has bedeviled Canadian science policy more than the conventional view of the relation between basic or curiosity-oriented research and innovation. Volume 1 of our report showed that for the half century following the setting up of the original National Research Council no one

ever seriously questioned the theory that there was an unbroken spectrum from basic research through to innovation. It was held as an article of faith that innovation in the industrial sector depended on this continuum and that the way to strengthen and enlarge Canadian industry, therefore, was to set about conducting basic research. That this view is still deeply engrained in Canadian institutions and organizations was made clear in a number of briefs commenting on Volume 2.

The Association of Consulting Engineers of Canada believes in the continuum theory. Its brief stated:

> . . . The Senate Committee might have shown a lack of confidence in *the closeness of the link between pure science and industrial innovation.* It should be pointed out that there can be no sharp distinction between mission-oriented and basic research, that those involved in industrial technology must have contact with basic science in order to innovate.[5] [Emphasis added.]

Some industrial associations also expressed concern over the proposed separation between basic research and the rest of the supposed sequence leading to innovation. For example, the Electronic Industries Association of Canada declared:

> There are four recommendations (nos. 6, 7, 18 and 19) which contain the implicit threat of isolating the activity of basic research from that of applied research. The Association is deeply disturbed over the reality of this threat and its serious consequences insofar as the development of technology is concerned. *The cross-fertilization between pure and applied science is so important and so manifestly rooted in the whole history of science and technology that it is inconceivable that their segregation should be seriously considered.* It is surprising that the Senate Committee would sanction their separation in favour of the much less promising association of multi-disciplinary basic research and multi-disciplinary applied research.[6] [Emphasis added.]

SCITEC also subscribes to the continuum theory of innovation. The association held a special two-day meeting in Ottawa in October 1972 to consider the recommendations in Volume 2. The position paper summarizing their discussions noted:

> There was strong agreement that any new institutional structures should be based on a recognition of the continuum which embraces all stages from basic science, through applied science, development and innovation.[7]

We could quote several other briefs to show that this same theory offered by Dr. A. B. Macallum in 1919 is still accepted in Canada as an axiom. Indeed, we should emphasize that at the beginning of our inquiry we had no preconceived view of the theory. We began to question its validity while preparing Volume 1, when we observed that after 50 years of acceptance in Canada it had still not worked.

Our country was not the only one to base its science policy on faith in the unbroken-spectrum theory of innovation; Britain also accepted it for many years. The Report on Science Policy issued by the Council for Scientific Policy as recently as 1967 was in effect a lengthy promotion for pure science based on the premise that science is the prime supplier of the new knowledge needed to advance society, a premise clearly expressed in the well-known sentence:

> Basic research provides most of the original discoveries and hypotheses from which all other progress flows.

However, the Council for Scientific Policy later abandoned this view. In fact its working group on economic benefit went so far as to conclude that "curiosity-oriented research is only rarely the main spring of substantial innovation." The council finally considered it more accurate to describe such research as "providing an infrastructure on the basis of which innovation or improvement in technology is possible," rather than as the prime source for technological development.[8]

One reason for the long life of the spectrum theory is that basic scientists, in order to obtain funds, have found it necessary to argue that practical results would eventually stem from their work and that if the nation wished to develop practical innovations it had to back basic research. The literature of science policy is rich with evidence to this effect. C. West Churchman notes that in considering the basic research system as a whole, "one cannot distinguish between science and its politics." He goes on:

> Many scientists these days extol the virtue of basic research which has no apparent purpose other than to reveal some aspect of nature. In the eras of cost cutting, they urge the funders to support them because who knows what fruits basic research may eventually produce; they go on to mutter about transistors, atomic energy, polio vaccines, and biochemical warfare. What a crass way to defend the glory of basic research.[9]

When we began the preparation of Volume 2, we had developed sufficient doubt about the continuum theory to decide that it could not be accepted as an axiom, as it appeared to rest on personal prejudices and interests. We studied what the historians of science and technology had to say on this subject and the findings of empirical studies then available to us. In Chapter 12 we presented a summary of the literature. We referred to the comprehensive study, *The Conditions for Success in Technological Innovation*, published by the OECD, to the survey entitled *Successful Industrial Innovations* made by D. G. Marquis and S. Myers, to the Hindsight and TRACES studies, and to several other expert studies on the innovation process. We found that all the empirical evidence showed the continuum theory to be wrong in most cases in the

real world. We quoted one of the OECD study's conclusions about basic research:

> The characteristics of such research are often very low probability of success, relatively low cost, very high pay-off if successful, but pay-off only in the long term—up to thirty years according to the evidence presented elsewhere in this report.[10]

The Committee was surprised at the number of critics who upheld the continuum theory without even trying to contradict the evidence we presented or to submit empirical findings to support their own views. There can only be two possible explanations: either they chose to ignore the facts in order to preserve their faith or they did not read the evidence presented. The second explanation is probably the true one. Chapter 12 did not contain any specific recommendation and so did not attract much attention from our readers. Whatever the explanation, disagreement about the continuum theory remains an important issue in Canada. Because of its important practical implications, the Committee wishes to put in new findings in the hope that a greater and more realistic consensus can be reached, which would facilitate the implementation of an overall plan of reorganization.

Stephen Toulmin, in the first volume of his ambitious work on *Human Understanding*, has made an exhaustive study of the interaction between science and technology. He writes:

> Historically speaking, in fact, science and technology have developed hitherto independently and in parallel. . . . If in recent years the development of the technical and industrial arts has seemingly been 'revolutionized' by science, we must not be misled. This does not mean that the essential nature of technology has in any way changed; only that its contemporary partnership with science has accelerated the solution of technical problems which had previously been intractable.
>
> Even so, our recent experience with such science-based industries as electronics and pharmaceuticals may be unrepresentative. Rather than giving rise to brand-new technologies and industries, science-based innovations more typically help an existing technology to solve its own previous problems more rapidly. For a long time, indeed, they may not even succeed in doing that much.[11]

Toulmin's observations have been confirmed by recent empirical studies. One of the most significant is Project SAPPHO, conducted by the Science Policy Research Unit at the University of Sussex. The Centre for the Study of Industrial Innovation has published a brochure describing some of its highlights:

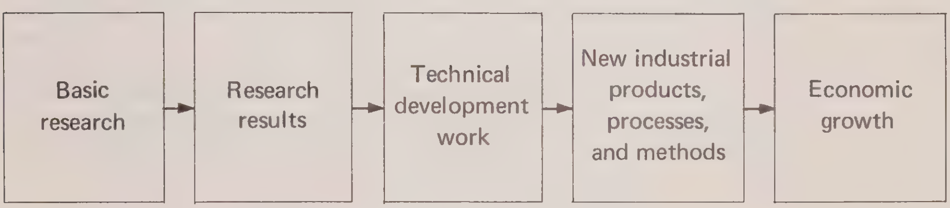
> It has sometimes been suggested that a proportion of basic research adds to the strength of an R&D department. In about half our cases basic research was being performed in the firms (mainly in chemicals) but there was only a modest association between successful innovation and the performance of basic

research by the firm. Casimir and others have suggested that basic research is a source of innovation that cannot be ignored. The SAPPHO results do not contradict this but indicate that it need not necessarily be conducted within the firm.[12]

In other words, basic research can be conducted in a separate organization such as a university or government basic research laboratory. It is probably much better for a firm or government department to consult with the most able researchers in basic research organizations rather than employ second or third rate scientists in its own institution.

The relation between science and innovation has also been studied in Sweden. Erik A. Haeffner of the Institutet för Innovationsteknik (the Innovation Institute) in Stockholm has recently written on the innovation process.[13] Dr. Haeffner, managing director of the institute, presents a diagram (Chart 20) of the Innovation Chain "popular in the 1950s," and says it is "improbable because it presupposes that there is no dependence between the intensity or occurrence of technical development work (innovation activity) and the economic conditions in an industry."

CHART 20



The "Innovation Chain," embodying the belief, popular in the 1950s, that new knowledge—the result of pure scientific research—would automatically lead to innovations in industry and economic growth.

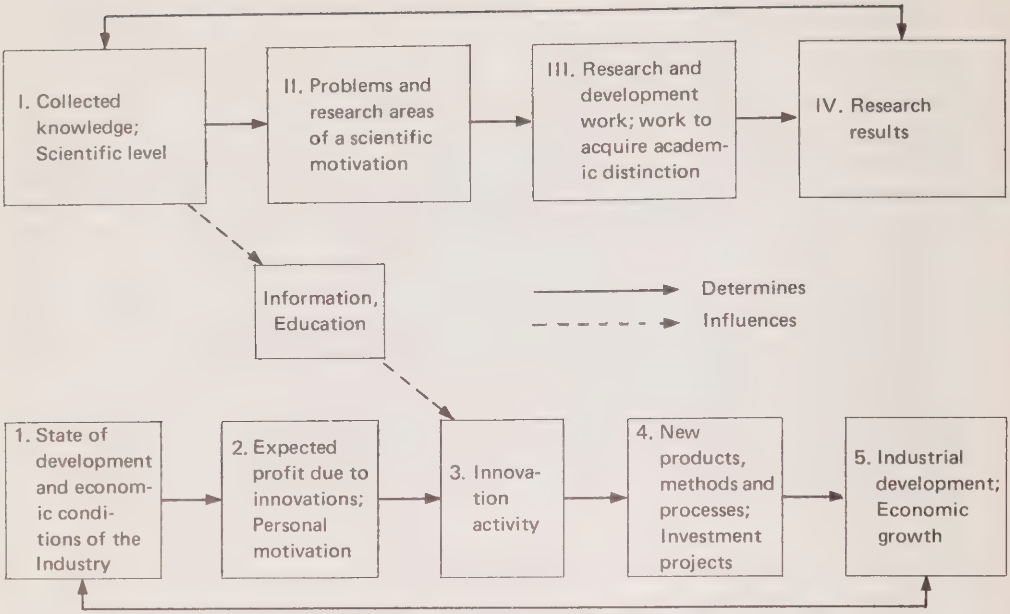
SOURCE: Erik A. Haeffner, "The Innovation Process", *Technology Review,* March/April, 1973, p. 19.

In another model (Chart 21) he shows the relation between science and innovation that he thinks more accurately represents the real world.

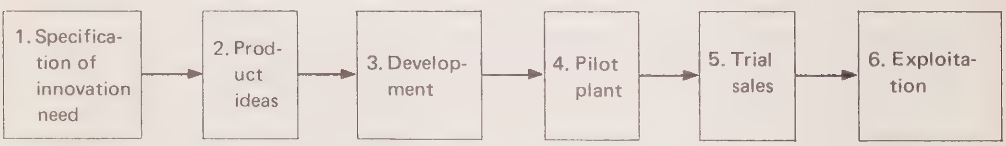
He declares:

It also happens occasionally that a creative research worker makes a scientific discovery that is comparatively ready for technical or other application. Yet generally, scientific research according to the top line [of the chart] differs from technical development as represented by the bottom line in regard to motivation, method of working, objectives, and staff requirement. And the findings which we [have made] . . . do show that investment in large research laboratories and research staff is hardly suitable as a means of achieving economic growth, an experience which many industrial companies have had to face.[14]

CHART 21



A model for technical progress and economic growth. The activity across the top of the model represents scientific research; the activity across the bottom represents development in industry. Research has one primary effect: it increases the body of available knowledge, and this knowledge affects innovation. The impetus to innovation, however, is the state of the industry, and the industry's expectation of profit arising from the effort. *In the illustration below, "innovation activity" (box 3 above) is further dissected.*



SOURCE: Erik A. Haeffner, "The Innovation Process", *Technology Review,* March/April, 1973, pp. 20-21.

He goes on to point out that if the new model presents a correct picture "then it means that only few innovations can be described as direct results of pure research and that the bulk of the inventions and innovations which are responsible for industrial growth occur in some other way. . . . There is a surprising amount of evidence in support of the model." Dr. Haeffner mentions the Myers and Marquis study, which the Committee referred to in Chapter 12: of 567 commercially successful

innovations, only 3 per cent could be identified as being initiated by research.

For some years the British government has been giving the Queen's Awards to Industry to firms that have made significant technological innovations. In 1966 and 1967 a total of 84 awards were given for successful innovations. These have been subjected to detailed scrutiny by staff members of the University of Manchester's Department of Liberal Studies in Science.[15] This study throws considerable light on the relation between basic science and innovation as well as on other important factors affecting innovation. The Committee believes it is worth reflecting on the results of this study in some detail.

In the introduction, Prof. F. R. Jevons states that the predominant emphasis of the study was on "close-in assessments of the situations in and around the innovating firms with appreciation of the technical issues involved. The case-study approach has continually rubbed our noses in the facts; our book contains more of the complex realities of history 'as she really happened' than of the abstractions and conceptualisations which achieve intellectual economy at the expense of fidelity to the real world."[16] The study finds that the continuum theory linking basic research directly to innovation is just such a simple abstraction.

Another introductory comment of Professor Jevons's is worth reading in full:

> We have paid particular attention to the relation of basic science to innovation. To our minds, our failure to find more than a small handful of direct connections is the more striking for the fact that we set out so deliberately to look for them. Our conclusions on this point have proved unpopular in some quarters. Some academic scientists find it difficult to accept what most businessmen already know: that the great bulk of basic science bears only tenuously if at all on the operations of industry. D. S. Greenberg has made some perceptive comments on this kind of situation in *The Politics of American Science* (Penguin Books, 1969, chap. 2). Science, he points out, is neither self-explanatory nor self-supporting and scientists tend to react to this predicament with a mixture of chauvinism, xenophobia and evangelism. Stirring professions of faith in basic science are coupled with dire prophecies that technology will die on the vine if it is starved of the rising sap of new ideas from undirected research. But in the long run, more solid reasons will be needed to ensure continuing public support for science on a large scale. In presenting our conclusions, we certainly do not intend to denigrate science; rather, we want to urge recognition of the fact that its value to industry is less direct and less overt than has been commonly supposed in the past. Perhaps science is not the father of technology but an anonymous well-wisher who sends it gifts through the post, as it were. If only the mechanism were more clearly understood there would be a better chance of increasing the benefits, and the justifications for public support of science would be strengthened.[17]

The study considers the relation between science and technology and notes, "We fail to find much direct input of basic science into innovation but believe that there is a substantial contribution in various latent forms."[18] For example, science may lead to innovation once it is embodied in technological form. It may be rare for a piece of curiosity-oriented research to generate a piece of new technology, but when this has happened the technology can be used over and over again and developed into more advanced technology. The authors think there is justification for the view of Derek de Solla Price that technology builds largely on earlier technology:

> The naïve picture of technology as applied science simply will not fit all the facts. Inventions do not hang like fruits on a scientific tree. In those parts of the history of technology where one feels some confidence, it is quite apparent that most technological advances derive immediately from those that precede them.[19]

Incidentally, J. Herbert Holloman, director of MIT's Center for the Study of Policy Alternatives in the School of Engineering, agrees with this view:

> New technology flows from old technology, not from science. . . . Most technological developments . . . go one step at a time: improvement of artifact or process, and then a gradual cumulation of the state-of-the-art rather than a gradual cumulation of the literature of science. . . . The support of science is not a *sine qua non* for economic and social development. More often it is not that science produces wealth but that wealth can support science.[20]

The authors of the Manchester study conclude that probably the most important justification for supporting basic science is its use in training specialized manpower:

> There are, of course, non-economic reasons for pursuing basic science—culture and prestige, for instance—but in most circumstances these are not felt to justify expenditure of really large sums on a continuing basis. Support on anything like the present scale must, therefore, rest on prospects of economic returns of some kind. We can identify three main ways in which science can bring economic benefits. Scientific discoveries occasionally lead to applications in the form of new technology; this is rare, but the effects may be multiplied indefinitely as technology builds on technology. Science also provides techniques which make it possible or easier to tackle industrial problems successfully. Finally, basic research is an element contributing to the output of highly qualified men and women educated in science and its methods. Of these three factors, the manpower benefit may be the most important when the justifications for basic science are considered in the national context, partly because discoveries and techniques cross international boundaries more easily than men.[21]

The statistical data obtained by the Manchester group show clearly that the old, conventional-wisdom model of innovation—"science discovers, technology applies"—does not explain innovation except in a few cases.

Out of 111 innovative events, only two were science-push and 35 technology-push, while 74 arose from the needs of customers or company managers.[22]

Dr. Keichi Oshima, a professor of chemistry who is also a member of the advisory committee on technology policy to the Minister of International Trade and Industry in Japan, has written on the subject of technological innovation, emphasizing the quality of manpower as a major factor in Japan's notable success in innovation.[23]

Dr. Oshima's views tend to agree with those of the Manchester group:

> We have to admit that most basic research in universities and public institutions had little direct link with technological innovations in industry, but its most important contribution was to supply general scientific and technological background for them.[24]

Dr. Oshima makes another important comment on this subject:

> While the percentage of students of natural science and engineering in higher education is about 20%, much lower than European countries, the proportion of engineering students among this group is extremely high, more than 70%. This trend indicates that the education policy of the government is influenced by the demand of industry for high-quality technical manpower.[25]

That is to say that Japan, unlike Canada, produces relatively more engineers suitable for employment by industry than basic scientists.

As we showed in Volume 1, the Canadian government has been continuously tempted to back large prestigious technological projects in the hope that there would be innovational spin-off. Recently Canadian science policy commentators have again called for major national programs. Dr. Oshima expresses his concern about such a strategy:

> However, large government expenditure on big national projects should not be overemphasized. The technological innovations resulting from big national projects are not necessarily important for the growth of the national economy. In some cases, these even have a negative economic effect by tying down scientific manpower to a non-economic sector.[26]

In an article summarizing the literature on the relations between R&D and economic growth, Charles T. Stewart, Jr. says:

> R&D is not homogeneous, but a varying mix of basic research, applied research, and development. The relation between basic research and economic growth is remote at best: that between development and growth is closer in function and in time. The major interest in research data at the more basic end of the spectrum, so far as growth is concerned, is the role of basic research in raising the productivity of applied research and development, in creating new opportunities for expanding the technological frontier of society.[27]

During its visits to various countries, the Committee had the opportunity of discussing this topic with many scientists and administrators who had

first hand experience with successful innovation. When the conventional innovation model ("science discovers, technology applies, and innovation occurs") was mentioned, the mildest response of the experts was "Nonsense!" Several added, "That is a myth I used to believe a long time ago, before I knew anything about innovation," confirming Dr. Haeffner's observation that the continuous spectrum theory was a popular belief of the 1950s which empirical studies have since shown to be "improbable."

The Committee is concerned that this theory is still popular in Canada in the 1970s not only amongst scientists but even within the engineering community. The survival of the myth can only be explained by lack of research on research in Canada, which the Committee deplored in Volume 2, and by the failure of the scientific and engineering community to acquaint itself with the growing empirical findings available in the science policy literature and with experience abroad. We hope that the evidence presented in Chapter 12 of Volume 2 and in this chapter will help to erase the myth and lead to more realistic views of the innovation process.

We want to emphasize that in rejecting the unbroken spectrum theory we do not intend to downgrade basic research. Our support for this scientific activity was clearly indicated in Chapter 14 of Volume 2. We believe, however, that it is essential to understand its specific features and requirements, its purposes and role if the government is to formulate a coherent science policy and design a proper system of organization for its implementation.

If the spectrum theory is "improbable," this means that the innovation process can be broken down into different stages as far as organizational structures and sectors of performance are concerned. Even those who support the theory accept this proposition, which shows at least that they are inconsistent. Indeed, there is general agreement that universities are the ideal location for curiosity-oriented basic research and that industry constitutes the best place to carry on development work. The Committee is convinced that SCITEC, for example, would accept this view and yet this organization says science policy should be "based on a recognition of the continuum which embraces all stages from basic science, through applied science, development and innovation."

While most of our critics agree that basic research should be done mainly in universities and therefore separated from the other stages of the innovation process, they are opposed to an organizational separation that is much less rigid when it comes to government support or performance of this scientific activity. For instance, SCITEC stated, "There was strong agreement that any new [government] institutional structures should be based on the recognition" of the continuous spectrum theory. The logical conclusion of this assertion is that all R&D activities should

be conducted entirely in universities or entirely in the government or entirely in industry.

The Committee feels it has adopted a more consistent and realistic position. We have argued—and continue to do so—that a flexible organizational separation between basic research and the other stages of the innovation process is not only possible but also desirable.

THE GUIDING PRINCIPLES OF THE PROPOSED REORGANIZATION PLAN

The plan of reorganization for departments and agencies submitted in Volume 2 was inspired by the requirements of the innovation process revealed by the empirical studies available to the Committee. It was also influenced by the principle of *division* of labour, by the desirability of avoiding conflicts of interest, and by concepts of specialization and integration.

When the Canadian government's involvement with science and technology was small it was not always possible to apply these principles because the overhead costs involved would have been too high. Multipurpose agencies, such as NRC, were then probably the only practical answer because they reduced administrative costs when budgets were small.

These conditions change, however, when government involvement grows larger. The inherent deficiencies of multipurpose agencies, such as conflicts of interest and the incompatibility of functions, become more obvious and obstructive. It is also possible to correct these deficiencies through a better division of labour and greater specialization because administrative overhead costs tend to decline, in relative terms, as budgets increase.

Greater specialization means more agencies but does not necessarily increase the danger of administrative confusion and overlapping. The strong central machinery we proposed earlier should minimize this danger. Moreover, specialization is not incompatible with integration. Specialized agencies with parallel but similar missions could be brought under the umbrella of a single administrative organization to reduce overhead costs, avoid overlapping, encourage multidisciplinary undertakings, and facilitate personal contacts.

The Committee favours coupling specialization with integration. Donald V. Fowke has insisted on this point:

> Organizations are thought to be *either* centralized or decentralized. In the face of uncertainty, organizations must be *both*. . . . The concepts of differentiation and integration provide a more precise way of looking at the decentralization-central-

ization question. According to research done by Lawrence and Lorsch, organizational units should be highly differentiated where there is:

1. Lack of clarity in the information on which decisions must be made,
2. Uncertainty regarding cause and effect relationships, and
3. A long time span in the feedback of the results from a decision.

Differentiation implies a specialization of organization units, an adaptation of their styles of management to the requirement of their particular environments. For overall adaptability, however, organization units must not only be highly differentiated but they must also be highly integrated.[28]

These three conditions are more likely to be found in the field of science and technology than in any other sector of public policy, and this is precisely why science policy requires highly differentiated and highly integrated organization units. That basic requirement has inspired the Committee's overall approach to the organization of government scientific activities. Most of the recommendations made in Volume 2 provide for highly differentiated organizational units capable of reacting effectively to a specific function or responsibility but also sufficiently integrated to profit from the advantages offered by centralization.

We now re-examine those recommendations in the light of the discontinuous spectrum theory of the innovation process and of the guiding principles just mentioned, also taking note of the comments and criticisms received since the publication of Volume 2.

THE GRANTING INSTITUTIONS

For the academic training and research sector we proposed the creation of a Canadian Research Board and of three foundations "to report to the Secretary of State and to be responsible mainly for the development of a capacity for and the support of curiosity-oriented basic research in universities and similar institutions"[29] in the physical sciences, the life sciences, and the social sciences and humanities.

In substance, this recommendation merely made explicit what is already implicit in existing agencies. It was not, as some claim, a revolutionary change but an evolutionary one, inspired by recent growth and progress that have put the Canadian government in a position to organize its support for academic training and research with better regard for the principle of the division of labour and along more functional lines.

For example, we proposed the separation of NRC's granting function from its research operation. This issue is not new. Back in 1951 the Massey Commission indicated there was already some concern in Canada about the incompatibility of these two NRC functions. In a review of Canada's science policy published in 1969, the OECD's exam-

iners echoed these worries and recommended that the support of curiosity-oriented research in universities and similar institutions should be separated from the council's laboratories and assigned to a special body. In the same year, the report of the Macdonald group came to the same conclusions, recommending that " . . . the National Research Council be reconstituted so as to have as its sole responsibility the support of scientific and engineering research in universities and related institutions." In his last annual report as chairman of the Science Council, Dr. Omond Solandt concluded:

> I believe that it is important for NRC to relinquish its role as a major granting agency for the support of university research.[30]

Four institutions that had carefully studied this problem came to the same conclusion. The Senate Committee agreed with it and added a few arguments to support the separation of functions.

Other countries have clearly recognized the conflict of interest implicit in making a government agency responsible not only for giving grants but also for running its own laboratories. For example Dr. C. H. Townes, who won the Nobel prize in physics for his role in the invention of the maser and laser, writes:

> A government agency is naturally concerned about the fate of one of its own laboratories, and may hence be overindulgent. This instinct is particularly hazardous when the same agency, perhaps even the same individual, is responsible for initiating or maintaining the laboratory, as well as for making decisions on competing bids by other institutions for research support. There are, of course, valid reasons for some laboratories to have much better facilities than others and different styles of operation. However, some of this unhealthy disparity often evident between government laboratories and others could probably be avoided by administrative care to remove the decisions on granting agency funds for supporting research from those who have a special and personal interest in the maintenance of one of the agency's own research laboratories.[31]

The Committee believes it is administratively inept to make agencies responsible for grants for research projects or equipment that their own staff might wish to have. An agency is put in an unenviable position when it must decide whether a university group should be given grants to pursue projects that its own staff consider their prerogative.

We came to the conclusion that support for academic research in the life sciences, including biology, had been relatively neglected under the existing system and that it had a greater affinity with medical research than with the physical sciences. We were impressed by Dr. Steacie's comments in this respect. We are still convinced that the name of the Medical Research Council should be changed and that its activities should be extended to all the life sciences. In our view, this would be a

real improvement over the present situation though the change involved would be far from revolutionary.

We also proposed a foundation for the social sciences and the humanities, separate from the Canada Council. This recommendation has received strong support. We will quote only from the two main national organizations most directly concerned. The Humanities Research Council of Canada states:

> We recommend therefore, that the humanities and social sciences division of the Canada Council should be recognized more formally as the funding organization for the humanities and social sciences, and put on an organizational footing equal to that which exists for the natural, physical and health sciences. We therefore find ourselves in general accord with the recommendation of the Senate Special Committee on Science Policy that a separate 'foundation' for the humanities and social sciences be established provided that the expertise and the administrative personnel of the humanities and social sciences division of the present Canada Council could be utilized by the new body.[31a]

The Social Science Research Council of Canada has issued the following statement:

> The Canada Council in its present form is no longer a satisfactory body for the social sciences. It must be changed. The Canada Council should be split in two distinct bodies, one for the humanities and social sciences, and one for the performing arts. The Humanities and Social Sciences Division should be absorbed by a humanities and social sciences research council as is now proposed. At present, the Humanities and Social Sciences Division is responsible to an appointed council, many of whom are not familiar with the social sciences or humanities. When one compares the nature of this appointed council with that of the NRC or the MRC, one is struck by the absence of professional expertise in the appointed membership of the Canada Council.
>
> Surely it is time that the important role played by the Social Sciences and Humanities Division be recognized and that the division be put on an equal footing with the physical and health sciences which have in their own appointed councils (NRC and MRC) a high degree of professional competence and expertise. . . . A separate 'foundation' for the humanities and social sciences, such as is recommended by the Senate Special Committee (Volume 2, page 432) would meet this difficulty.[31b]

There has been some misunderstanding about the role proposed by the Committee for the three foundations. Some people have interpreted our recommendation as meaning that the foundations would be restricted to the support of basic research and that it would be difficult and perhaps undesirable to make a distinction between pure and applied research. But our recommendation specified that the foundations "be responsible mainly for . . . the support of curiosity-oriented basic research. . . ." This was a question of emphasis, not of exclusion. Indeed, we had earlier stated:

> The support of scientific surveys and applied research [conducted in universities and similar institutions] should be assigned *mainly* to mission-oriented agencies. The assistance provided by the federal foundations proposed below for these purposes would be residual and available only in areas where there were no other specific federal agencies.[32] [Emphasis added.]

In other words, here again we applied the principle of the division of labour. Applied and engineering research as well as scientific surveys, even when they are carried out in universities and similar institutions, must correspond to a need or practical objective. Mission-oriented departments and agencies are in a much better position to perceive needs and problems than the existing councils or the proposed foundations. These scientific activities must be demand-pull; but good curiosity-oriented basic research must be supply-push. These different requirements could be respected if mission-oriented departments and agencies were *mainly* responsible for supporting extramural demand-pull research and development through contractual arrangements. Such a system would be no more than another application of the government's new contracting-out policy. If it were implemented the foundations would be able to concentrate their efforts on supply-push basic research. In that context, we agree with Dr. Solandt:

> In discussing federal support of research, especially in universities, there is a tendency to think of the granting councils as the sole source of federal funds. It is often overlooked that the mission-oriented departments can, and to a limited extent do, support research outside the government both by grants to universities and by contracts to industry. The Science Council has seen the two sources of funds, the granting councils and the mission-oriented departments, as having complementary, but not competitive, roles in supporting research.[33]

Such a division of labour would not guarantee that undesirable gaps and duplication would be avoided. But if the Ministry of State for Science and Technology were made responsible for reviewing and assessing all government programs designed to support research in universities and similar institutions, it would be in a good position to detect imbalances, make proposals to correct them, and ensure that the foundations and the mission-oriented departments play complementary rather than competitive roles. The ministry should also have enough authority to convince departments and agencies to give more adequate support to applied research and engineering in universities and similar institutions. It is common experience that the most successful laboratories of government departments and agencies closely integrate their in-house research efforts with their management of external development contracts; MOSST should induce departments and agencies, in co-operation with the Department of Supply and Services, to develop this balance of expertise.

We do not believe we created an artificial and undesirable distinction between basic and applied research and development in assigning complementary roles to the foundations and to mission-oriented departments and agencies. Indeed, it is vital that *user need* be directly associated with applied research and development. Also, we believe, the proposed arrangement would be highly flexible and would guarantee a more balanced support of the different types of research that should be carried out in universities and similar institutions.

Some concern has also been expressed that the creation of the foundations would isolate pure scientists from professional workers. For instance, the Association of Professional Engineers of Ontario stated:

> Briefly, we feel that we can endorse this recommendation only if, at the same time, adequate provision is made for the curiosity-oriented basic research worker to interact with his professional colleagues engaged in the exploitation of the knowledge gained.[34]

It is important to note that the existing granting councils offer no such provision. Indeed, no system of support for scholar-initiated research can in itself prevent isolation; other mechanisms and services are needed. The Committee has suggested a national conference of the academic, professional, and industrial sectors to devise, among other things, "the best possible permanent institutional basis for maintaining a continuing liaison and cooperation in the future."[35] But more contact between the segments of the scientific and engineering community is not enough. As the Committee has said repeatedly, Canada can only produce a small portion of the new knowledge generated in the world. That is why we have proposed new and more effective scientific and technical information systems to give our scientists and engineers easier access to new knowledge produced in Canada and abroad.

Some other reactions to the proposed foundations must be mentioned. The report of the SCITEC workshop which dealt with basic research and the foundations at the October 1972 meeting states:

> We could find no compelling justification for establishing a new trio of foundations which might cause disruption of the current effectiveness of the granting role of existing agencies.[36]

In view of all the representations favouring changes in the granting organization of the Canadian government, we find this defence of the status quo untypical and rather surprising. We remain convinced that the proposed changes would rather improve than disrupt the current effectiveness of existing agencies. They would provide for a more logical and realistic arrangement.

Another reaction goes in the opposite direction and calls for a drastic reform that we cannot accept. The Canadian Manufacturers' Association

comments, "There should not be a proliferation of agencies, a more highly complicated structure, or one that functions no better than those of present known quality."[37] It suggests the Canadian Research Board should be "concerned with the support of all university research rather than the support of basic research only."[38] Dr. Solandt has suggested the reorganization of the granting function "into a single body that would be internally organized into suitable components to cover the entire spectrum of research in the natural, social and life sciences. Such a body would take over the university-oriented granting functions of NRC, those relating to basic research from the Medical Research Council, and support of research in the social sciences and humanities from the Canada Council."[39] The OECD examiners proposed a similar arrangement.

The full integration of the granting function, even if it were concerned mainly with basic research would meet with strong opposition from the scientific community. The three main areas of scientific disciplines are sufficiently different and their financial support is sufficiently large to require separate, specialized bodies responsible for the allocation of funds to scholars.

It is interesting to see how these matters are arranged in other countries. In Finland there are six research councils, one each for the humanities, the natural sciences, the medical sciences, agriculture and forestry, the technical sciences, and the social sciences, which share an administrative and financial bureau under one umbrella organization called the Central Board of Research Councils. The board is serviced by several planning committees, and this whole complex is called The Academy of Finland and reports to the Science Office of the Ministry of Education.

In Great Britain, there are five research councils. Commenting on this situation, Sir Frederick Dainton has said:

> Although our arguments would seem to point to the establishment of a monolithic National Research Council we are opposed to this solution. A single Council given authority and responsibility over the whole range of strategic and basic science might become too remote from the scientists actually carrying out the work; there would be a serious danger that a paralysing bureaucracy might develop. There would also be a risk that if the grant-giving authority were monolithic, its errors would have graver consequences.[40]

The Committee remains convinced that the three foundations it has proposed are necessary. The need for greater co-ordination between them is universally recognized, however. As the Canada Council put it, closer liaison is desirable "to ensure complementarity between services and consistency between programs and in order to foster interdisciplinary undertakings."[41]

The Committee proposed a Canadian Research Board composed of a full-time president with a small secretariat and the chairman of the three foundations. SCITEC's workshop on basic research and the foundations agreed that "to coordinate the development of a capacity for basic research, a Canadian Research Board might be set up," but added, "It should represent the diverse sectors of science, with functions clearly defined so as not to compromise unduly the autonomy of the present individual Councils."[42] The Social Science Research Council of Canada stated, however, "The main advantages of such a Board are already available through the informal Tri-Council Co-ordinating Committee."[43] It also worried:

> . . . the main danger of a permanent organization is that while it may be able to encourage multidisciplinary research that does not fall within any of the three foundations, it may exert influence over the proposed foundations restricting any policy-making role which they may have. As well, the mere fact of the Board's existence would place the foundations at a greater distance from the responsible minister. The Board, as proposed, (p. 438) would also appear to have no direct contact with the research communities it would be seeking to serve. Being made up of a President, and the Chairmen of the three proposed foundations, it might well become an isolated but still influential organization.[44]

The Committee does not share these fears and still feels that a greater integration of the foundation than is provided by an informal committee is desirable. We are inclined, however, to revise our views on the composition of the board. Its membership could be larger than the one we envisaged in Volume 2 and its president should act, at the beginning at least, only on a part-time basis.

Our conviction of the need for such a board was reinforced by the views expressed by Lord Rothschild and the Dainton working group in Britain. The Dainton group's report stated:

> We recommend that the activities of the Research Councils should be co-ordinated and administered by a Board, which would include as full members the scientific heads of the Research Councils. . . . We believe that the Board should be associated with the Department of Education and Science.[45]

Although Lord Rothschild wanted to retain the Council for Scientific Policy, his views on its composition and duties are similar to those proposed by the Dainton group for the board. He declared:

> The composition and duties of the Council for Scientific Policy should be as follows:
>
> (a) It should have a part-time independent Chairman, appointed by the Secretary of State for Education and Science with the agreement of the President of the Royal Society;
>
> (b) Its members should consist of an independent Chairman, the five Chief Executives or Controllers R&D of the Research Councils, the Chairman of

the University Grants Committee and four eminent, independent Scientists, but no Assessors;

(c) It should, as at present, have an extremely small secretariat, provided by the D.E.S.;

(d) It should *advise* the Secretary of State about the distribution of funds between the Research Councils. . . .[46]

To the extent that this recommendation applies to Canadian conditions, we agree with it. We add, however, that the Canadian board should also provide common administrative services for the foundations and take steps to ensure that their priorities include support for worthwhile multidisciplinary projects. We feel the board could play a useful role without directly intervening in the foundations' allocating of research funds.

Comments have also been made about our recommendation that the foundations and the board report through the Secretary of State. This proposal has received wide support. It has been suggested, however, that this responsibility be assigned to the Minister of State for Science and Technology. It should now be clear that this would be an undesirable arrangement, given the new role we propose for MOSST in Chapter 20. We wish to repeat that if the ministry is to function effectively as an impartial assessor of the scientific activities of departments and agencies, it should not be put in a position where it would have to defend any particular agency's budget.

The Committee believes its recommendations for the three foundations represent an evolutionary development based on established strengths. We also feel that the Canadian Research Board would give the granting structure more flexibility and the capability to change and evolve further in time. It would provide for a more economical administrative arrangement, an effective co-ordination mechanism, and a more orderly method of determining the funds to be made available to the foundations.

GOVERNMENT INTRAMURAL BASIC RESEARCH

In Volume 2, the Committee recommended "that in the future most basic research activities of the Canadian government be concentrated in a national research academy, with three institutes for the physical sciences, the life sciences, and the social sciences, with the purpose of filling gaps in basic research" and "that a substantial portion of the work of the institutes be performed at the request of government agencies and private firms on a fee basis."[47]

The criticisms made against these proposals represent a wide range of diverging views. At one extreme, Dr. Alexander King suggests that the NRC laboratories should be transferred to universities:

> The proposal to create a National Research Academy is interesting but smells a little of a device to cope with the intramural laboratories and activities of the NRC. These laboratories have had an important function in the past, but there is doubt in most countries as to the wisdom of maintaining governmental or semi-governmental research institutes for basic research, whether pure or mission-oriented, separate from the teaching function. Would it not be wiser to come clean and, if it is decided that the NRC laboratories have served their purpose, to convert them gradually to become institutes of the Ottawa universities, well placed by geography to carry out many contracts for the government agencies but related essentially to the academic and teaching functions?[48]

At the other extreme, the workshop on the National Research Academy at the SCITEC meeting 1972 recommended keeping the status quo because "there was no agreement on a clear-cut definition of 'basic research'." The workshop report notes that the members could not agree that basic research done in government laboratories should be dissociated from other research activities (the traditional Canadian view). The position paper summarizing the SCITEC forum states simply:

> The forum agreed that most in-house basic research should not be concentrated in a National Research Academy as suggested in the Senate Committee Report. It was thought, however, that there may be a need for a new National Institute for the social sciences.[49]

The Canadian Chemical Producers Association expressed concern lest the "separation of the sciences into three institutes may tend to institutionalize the barriers to interdisciplinary teams and the rapid changes of emphasis characteristic of modern science."[50] The Pharmaceutical Manufacturers Association of Canada endorsed the National Research Academy recommendations but added, "Obviously they will be subject to modification on their way to implementation as other sectors of the scientific community make their feelings known."[51] The Association of Consulting Engineers of Canada suggested the board should in addition manage the basic research conducted within the government and also expressed its concern at separating science into three areas.[52] A large, Canadian-owned, international, technological corporation made the same proposal but urged that the curiosity-oriented research academy should not itself initiate, sponsor, or accept overall responsibility for either mission-oriented or profit-oriented investigative activity.

The Alberta Society of Petroleum Geologists (now Canadian Society of Petroleum Geologists) agreed "with the concept of research institutes, but would urge most strongly that these be set up in association with universities, where strengths already exist in the various fields."[53] The

Electronic Industries Association of Canada said the recommendation "just fails to gain support" and expressed its concern over the separation of basic research from applied research and development.

The Association of Professional Engineers of Ontario took a similar view. It suggested basic research should be conducted in government agencies and departments which have a mission because "we believe that basic research in the Government establishments must be in support of a Government mission."[54]

Judging from the poll conducted by SCITEC early in 1972, the National Research Academy was strongly supported: 70 per cent of SCITEC's *official* response committee approved the recommendation and only 16 per cent rejected it. The SCITEC *national* response committee voted 56 per cent for and 24 per cent against the recommendation.[55] A major difference between the two was the fact that in the official response committee only 2 per cent were from the government sector whereas in the national response committee the government sector representation rose to 20 per cent.

In summary, three major criticisms were made against the proposed National Research Academy. First, the academy would isolate basic research from mission-oriented applied research and development. Secondly, the creation of three institutes would separate and isolate the main areas of scientific disciplines. Thirdly, the responsibilities assigned to the academy would destroy NRC's historical role.

We do not accept the suggestion that the role assigned to the proposed academy would unduly isolate basic research from the other phases of the innovation process. The division of labour that we have in mind is much more flexible than some commentators' interpretation of it. When we recommended that "most basic research activities of the Canadian government be concentrated in a national research academy," this obviously did not imply that mission-oriented departments and agencies would be prevented from carrying out any basic research at all. It meant that their role would be residual, thus avoiding a danger indicated by A. M. Weinberg:

> It is natural that as the laboratory loses its sense of mission, the management will ensure survival of the institution by drifting into basic research. . . . This drift toward basic research in a mission-oriented laboratory, if allowed to proceed unchecked, could destroy the laboratory's taste and capacity for getting on with practical missions.[56]

The Committee does not deny that mission-oriented departments and agencies may have real needs for basic research. We contend, however, that *most* of these requirements should be met by the academy on a fee basis, thus guaranteeing that only genuine needs would be expressed by the users and that a *substantial* portion of the government intramural

basic research activities would be directly related to applied research and development. These arrangements would bring basic research closer to the other phases of the innovation process rather than isolate it.

The Committee believes it has made the case for a flexible organizational isolation of basic research earlier in this chapter, but additional observations may be useful here. Howard M. Vollmer has drawn important conclusions from the pattern of the historic relations between basic science and technology development in technologically advanced countries:

> Although they have some elements in common, basic research and applied research are fundamentally different in their purposes or objectives, in their culture or predominant value patterns, and in the style of management and organization they require. Therefore there is a need for organizational insulation between basic research and applied research activities.
>
> Since they are different but increasingly interdependent activities, there is a need for the development and strengthening of mechanisms for cross-fertilization between basic and applied research. The success of these mechanisms for cross-fertilization will not only contribute directly to the continued growth of both basic and applied research but also to the continued growth of technologically based societies and to the solution of major problems in these societies.[57]

We contend that the role we propose for the academy and the mechanisms we provide to relate a substantial portion of its activities to mission-oriented departments and agencies are in conformity with Vollmer's conclusions. Those who support the continuous spectrum theory of innovation often cite the fact that large high-technology companies do conduct basic research. It is, therefore, instructive to look at the Bell Telephone Laboratories in the United States, not only because it is one of the most notable examples of a firm that has successfully used basic science but also because its R&D budget is approximately the same as the total R&D expenditures of the Canadian government in its own laboratories. Dr. Harvey Brooks has commented:

> The Bell System represents the best example of a highly integrated technical structure in a high-technology industry and is widely regarded as the most successful and innovative technical organization in the world. It is often suggested as an appropriate model for what a federal scientific organization might become.[58]

The Bell Labs have three distinct groups, a basic research group, an applied research group, and a development and design group. The task of the central management is to see that the specialized goals of each section are relevant to the overall goals of the integrated system. The organization of the laboratories has been described by a vice-president, J. A. Morton.[59] He points out that there are two types of barriers between groups: space barriers (are the groups in the same building?) and organi-

zational barriers (do the groups report to the same manager?). Morton maintains that barriers are necessary:

> I can see that if I allow the feedback loop from design or manufacture to basic research to get very strong, the feedback will stop the basic research. And it won't be long before I've lost my research and perhaps my research people. *So we purposely put a barrier between manufacture and basic research*—either a space barrier or an organizational barrier, maybe both [emphasis added].[60]

Morton claims that similar barriers are desirable between basic research on the one hand and applied research and engineering on the other:

> But at the same time, we see that if applied people or engineering people can dictate what the basic research people do, they will kill the long-range basic research. So we need an organizational barrier: One man—Bill Baker—is head of all basic research; other men head up applied research and engineering. Our people are free to sell, to stimulate and motivate all they like. But my engineers and researchers, for example, cannot tell the basic researchers what to do. And conversely, the basic researcher who believes he has made an important discovery cannot order the applied research or engineering people to pursue it. So this organizational barrier provides freedom for basic research and freedom regarding what shall be developed.[61]

Thus we see that one of the most notable industrial laboratories, whose staff members have won Nobel prizes and other distinctions in fields of basic research, *purposely* inserts a barrier between the basic research group and the applied research, engineering, and development sections. It is true that the basic research group must work in fields conceivably relevant to the overall objectives of the company but otherwise the researchers are free to follow their curiosity.

The obvious conclusion to be derived from empirical investigations and the management practices of large research-intensive firms is that basic research laboratories should be loosely coupled with organizations conducting applied research and development and that a considerable amount of freedom should be given to basic science. That conclusion, in our view, justifies the establishment of a national research academy as we have proposed it.

In recommending that "a substantial portion of the work" of the academy "be performed at the request of government agencies and private firms on a fee basis," the Committee did not mean that this institution should be obliged to accept all the requests put to it or that it could not contract some of these projects out to universities and similar institutions. We wanted the academy to be loosely connected with mission-oriented departments and agencies but we agree with Morton that "if applied people or engineering people can dictate what the basic research people do, they will kill the long-range basic research." More-

over, we expect that in taking on contractual work the academy will leave itself ample opportunity to pursue worthwhile projects of its own.

In this general perspective we feel our proposal represents a more realistic recognition of the requirements of basic research than the contention of those who believe in the unbroken-spectrum theory—that most basic research should be carried out in mission-oriented departments and agencies. Not only would this produce research of poor quality but it would also inevitably lead to duplication and waste of scarce manpower and financial resources.

The second major criticism made against our recommendation relates to the isolating effect expected to result from the creation of the three institutes. The Committee was suprised by this criticism. Government intramural basic research activities are presently diffused through many departments and agencies. By concentrating most of these activities in three institutes operating under a single managerial board, we expected a closer integration of scientific disciplines, which would greatly facilitate multidisciplinary effort, not prevent it as has been objected.

We have had ample evidence before us to show that there is still a good deal of distrust between scientists of different disciplines and that the main scientific areas are at different stages of evolution. Moreover, expressions like "interdisciplinary" and "multidisciplinary" must not become catchwords which would make us forget that individual sciences and closely related scientific disciplines will always have specific interests and challenges deserving separate consideration. For all those reasons, it would certainly be unrealistic and unwise, at least for the 1970s, to conceive the academy as a scientific melting pot. Such an organization would be completely unmanageable and could not possibly become the centre of excellence we expect it will be in the not too distant future.

Nevertheless, the Committee reaffirms its conviction that sciences are becoming more and more interdependent and that multidisciplinary efforts will be increasingly essential for a better understanding of man and his world.

In the history of science, there have been many notable examples of disciplines interacting to produce new disciplines and new insights into the universe. One of the best documented cases in recent history is the development of molecular biology, a revolution that began when theoretical biology was taken over by men originally trained in physics.[62]

Sometimes the disciplines appear at first to be far apart. An example is the study of vigilance, which has been conducted for a little over two decades. Karl Pribram and Norman Mackworth consider that the history of research on vigilance and attention shows, "in the happiest possible manner, a general lesson or unwritten commandment for all investigators: love thy scientific neighbour; his ideas may soon become your own."[63] They say this research resulted from "one of the quietest

revolutions of our time . . . when electronic engineers and mathematicians (such as Tanner and Swets) dared to question some century-old ideas about the nature of human thresholds for sensory inputs."[64] This probing by mathematicians and engineers allowed psychologists to develop a new theory.

Basic research that allows scientists from many disciplines to interact is not only fruitful but, in the opinion of many, is becoming essential. For instance, Gabor Strasser asserts that "it is necessary to properly orchestrate the many disciplines" and that "superposition . . . simply does not work."[65] In other words, basic research on complex and socially important situations today requires a multidisciplinary approach in a coherent organization.

Some people are concerned because the Committee has suggested an institute of the social sciences within the academy. Once again, history has shown that there can be a fruitful interaction between the physical and social sciences. A Nobel prize winner for economics, Jan Tinbergen, who made notable advances in economic theory, came to this field as a physicist. More recently the economist Nicholas Georgescu-Roegen has argued that the economic process, instead of being a mechanical analogue as traditionally represented in economics, is an entropic process and has thus introduced concepts from thermodynamics into the field of economics.[66] Other cases could be cited. Recently there has been a fruitful interchange between control systems engineering and economic policy formulation. The British engineer-economist, A. W. Phillips (who developed the famous Phillips curve), demonstrated in the mid-1950s that economic stabilization resembled problems in engineering feedback control. But economists have only just begun to utilize the techniques of optimal control theory. The Harvard economist, Benjamin M. Friedman, says "these techniques are available and . . . [economists] haven't been using them."[67] Optimal control theory makes use of feedback information from the economy to guide the response of policymakers as the economy rolls along. Prof. Dov Pekelman of the University of Chicago says:

> Econometric models can only describe a system with mathematical equations. But control theory actually tells you what policy to use.[68]

Prof. Robert S. Pindyk of MIT describes it as "a set of mathematical techniques that tells us how to choose among alternative policies so as best to regulate or control a system."[69] Control theory also shows which type of policy works best for which objectives, what trade-offs exist between conflicting goals, and how well each objective can be met; how fast, for example, national income can grow and how low inflation can get. Apart from short-term stabilization problems, economists are beginning to use optimal control theory to determine hypothetical strategies for economic development, resource depletion, the regulation of natural

gas, price setting, control of the money supply, advertising expenditure, and financial management.

Once again we have a situation where much needed progressive development arises not from specialists working in isolation, but from a close interaction between fields of specialization.

Dr. Alexander King considers interaction between the social sciences and other disciplines essential if the problems society will have to face in the future are to be more clearly understood:

> These complex problems all possess economic, social, technological, and cultural elements and can only be approached by multidisciplinary teams working in a systematic framework. This solution will necessitate the development of a new type of software technology, falling somewhere between the social and the exact sciences. Much fundamental research is required which will come only partly from the behavioural sciences. The development of new methods and research skills may, therefore, become a major factor in science policy, requiring an integrated approach to research funding.[70]

Dr. King is impatient with the separation of scientific disciplines and puts the multidisciplinary approach in its contemporary perspective:

> Multidisciplinarity is, of course, a fashionable catch word, but it does reflect, if only primitively, a fundamental change in the evolution of scientific thought. The old classification of the sciences by the nineteenth century German giants into neat little boxes labelled chemistry, physics, botany, and so on, has already been modified by the arising of interface subjects such as biochemistry, chemical physics, or molecular biology: but this is just the beginning of a rediscovery of the unity and the inherently dynamic nature of the knowledge system. A group that has been working recently at OECD and will report shortly, considered the subject of brain and behaviour by bringing together a heterogeneous mix of neurologists, neuro-physiologists, bio-chemists, micro-biologists and psychiatrists, whose skills are collectively required for advancement of knowledge in this field. More and more as research evolves, we will be faced with temporary sciences; modes of concentration on problems at the frontiers of knowledge, where many disciplines, some of them already hybrid, will be required. The science of the future will have to be a quickly developing, kinetic coming-together of subjects, within the unity of all knowledge for which neither conventional university structures will suffice, nor the vertical governmental equivalents concerned with their application. Science is universal, three-dimensional and changing; to consider its finance needs within traditional classifications could lead to concentration of effort on the accepted, and to missing the new and significant.[71]

For reasons previously mentioned, the Committee has rejected the concept of full integration of government intramural basic research activities. We feel that the operation of three institutes under the auspices of the academy would provide a substantial improvement over the present diffuse situation. They would establish a better balance in the intramural

basic research effort and bring the different scientific disciplines much closer together so that multidisciplinarity, which most experts consider essential, could be developed more easily.

The third major criticism made against the proposed academy is that it would destroy the National Research Council. This was not our intention. We do not want our recommendation to be obscured or misunderstood as a result of disagreement over the name of the proposed enlarged basic research organization. We appreciate that the National Research Council was the mainspring of the Canadian attempt to build a national scientific capability and has great historical significance. We would therefore favour retaining the name to designate the academy.

Another important reason for preserving the name is that the intent of our recommendation was to realize the great aspirations of most presidents of the council. If we go back to the memorandum prepared by Dr. Tory in 1932, when he was president of NRC, which we reproduced as an appendix to Chapter 3 of Volume 1, it is quite clear that what he really wanted was to concentrate in the council the great bulk of the basic and long-term applied research carried out by the Canadian government.

Dr. C. J. Mackenzie, appearing before a House of Commons committee in 1950, declared that the type of men NRC required were the same as those sought by universities:

> And another thing, we don't want all the best men. That would be very bad. We don't want the practical men who would be the best men in industry. We are more interested in fundamental research and we are after the best men, men interested in such work. We are competitive with the universities. The type of person we want is the type of person universities want. There are many people, very competent, able men who are definitely the industrial type.[72]

It is also easy to see how Dr. Steacie envisaged the main role of NRC. He wrote:

> As far as the National Research Council is concerned, the list [of activities] includes fundamental work, long-term applied work with no specific objective, work on specific industrial problems, short-term industrial problems (i.e. ad hoc investigations), investigations for the services, consulting, testing, specifications and miscellaneous inquiries. All of these are of importance, but *it is essential, if the organization is to develop any reputation or scientific self-respect, that the ad hoc problems and routine inquiries shall not be allowed to force real research out of the door. It is very easy for this to happen, and in the case of many laboratories of similar type in other countries, it has happened. . . .* In my view, at least *as far as the National Research Council is concerned, long-term investigations, fundamental or applied, must constitute the major effort of the laboratories, if they are to keep the scientific reputation they have earned.* [Emphasis added.][73]

The Committee believes that the concern expressed by Dr. Steacie, that "short-term industrial problems" might "force real research out of the door," now represents a real danger. One reason for the Committee's recommendation that industrial research and "ad hoc investigations" should be transferred to the proposed Canadian Industrial Laboratories Corporation was precisely to make sure that good basic research should not be forced out of the door, as Dr. Steacie feared.

We feel that if the council is to increase its intramural activities in basic research and "long-term applied research with no specific objective," it cannot at the same time expand its effort to solve "specific" or "short-term industrial problems" without becoming too big and too incoherent an organization. This is another danger Dr. Steacie saw:

> One must also try to avoid the stifling effects of bigness. The tidy mind whose ideal is "one big organization" is the worst foe of originality, initiative, and scientific progress.[74]

If bigness is to be avoided, it would not appear rational to perpetuate the myth of the continuous-spectrum theory of innovation by having within one organization a large basic research operation along with industrial laboratories.

Thus we conclude that our recommendation to transform NRC into an institution for intramural basic research in the physical sciences, the life sciences, and the social sciences would not result in the "destruction" of the council. On the contrary, it would represent a reconstruction in the very direction that presidents of NRC really wanted but could not follow because they felt they had to hide some of their interest in basic research and show they were performing a practical mission. The implementation of our recommendation would enable NRC, for the first time in its history, to abandon this disguise, this false image. It would represent a most challenging mission, that of becoming a still better centre of excellence for basic research with a wider and more balanced range of scientific disciplines, a potential seed-bed for new mutations among existing scientific disciplines, a greater institution of which, the Committee is certain, all Canadians would be proud. The Committee is also convinced that Dr. Steacie would have picked up that challenge with great enthusiasm and would have been proud to head such a valuable and timely institution.

The Committee believes its recommendation would make the National Research Council what Alvin Weinberg called a coherent organization. It would have the balance between freedom and real-world constraint that is needed by basic science institutions. The change would undoubtedly enhance the quality of intramural basic research and minimize undesirable duplication. The council would have all the necessary resources for

developing as the kind of centre many experts consider essential for the future development opportunities of science.

Since Volume 2 appeared there have been many initiatives around the world to set up multidisciplinary research of a basic kind aimed at the complex problems of society today. For example, the International Federation of Institutes for Advanced Study (IFIAS) was established in 1972 under the auspices of the Nobel and Rockefeller Foundations, as a new instrument for trans-disciplinary and trans-national efforts among the physical, biological, and social sciences and the humanities. Dr. Sam Nilsson, executive secretary of the new organization, notes:

> IFIAS is one of a number of merging enterprises which reflect the need for new mechanisms and insight to help society cope with an increasingly complex, rapidly changing and interdependent world. It is expected that IFIAS would provide useful pilot models for such mechanisms. . . . By "trans-disciplinary", IFIAS affirms that its efforts in international co-operation transcend disciplinary bounds, not merely to join physicists to chemists or mathematicians to economists, but to bring to its programs and projects deep dimensions of concern with ethical, social and humanistic consequences of various lines of research and analysis, and with attention to the assessment of policy alternatives facing decision-makers in respect of new knowledge and its uses.[75]

Already IFIAS has member institutes representing ten disciplines and some 14 countries in North America, Latin America, Europe, Asia, Australia, and Africa. But Canada does not participate in its activities because we do not have the appropriate institutions. We would expect that a transformed National Research Council would fill this gap.

The Committee remains convinced that the proposed new National Research Council presents an important and exciting opportunity for the further development of science in Canada. Our country has enough skilled and distinguished scientists to develop this proposed organization into a great centre of excellence. Our main concern is whether there is the will and the managerial and administrative leadership to enlarge and run this great academy.

GOVERNMENT ASSISTANCE TO INDUSTRIAL R&D AND INNOVATION

Volume 2 included a set of specific recommendations designed to improve the organization of government assistance to industrial R&D and innovation. We limit detailed comment to the main proposals, which have met the strongest resistance from our critics.

1. *The Canadian Industrial Laboratories Corporation*

The Committee recommended that "laboratories operated by government departments and agencies for secondary and service industries as well as for mining and power utilities . . . be brought together in a new Crown company called the Canadian Industrial Laboratories Corporation (CILC) with a strong industrial representation on its board and committees and a growing industrial contribution to its financing and to be responsible to the Department of Industry, Trade and Commerce."[76]

The Committee noted with interest Dr. King's comment that "the proposal to bring the government's applied research laboratories together within a single Crown corporation, with strong industrial representation on the board and on its committees warrants close consideration. In nearly all countries, governmental applied research suffers from being too far from the user, and hence more intimate participation by industry is essential."[77] A manager of a large Canadian-owned corporation suggested that the CILC should be incorporated, like Polymer, rather than an unincorporated "body corporate" such as the National Research Council. In his view "the NRC structure was detrimental to NRC's meeting its objective of R&D for industry."

The Canadian Manufacturers' Association refrained from commenting on this recommendation "in view of the recently announced policy change whereby an optimum amount of government funded research will be contracted out to industry."[78] Other industrial associations expressed the concern that the operations of CILC would either interfere with industry or would conduct research and development which should be carried out within industry. For example, the Pharmaceutical Manufacturers Association of Canada stated in its brief:

> [The] Canadian Industrial Laboratories Corporation is looked upon with mixed feelings by PMAC. While recognizing the need for such a corporation in the special circumstances described by the Report, PMAC recommends that the Corporation exercise its functions in such a way that they will not interfere with the encouragement of research and development and innovation within the private sector of industry.[79]

The Association of Consulting Engineers of Canada, the Alberta Society of Petroleum Geologists, and the Electronic Industries Association of Canada expressed similar feelings.

In the Committee's opinion these fears are unwarranted. We did not propose the expansion of government industrially-oriented laboratories or the creation of new ones. On the contrary, we recommended "that a detailed and continuing review be undertaken by the Ministry of Science and Technology of current and future industrial R&D programs of

government departments and agencies"[80] to make sure that they are contracted out as much as possible to industry. We said:

> It should be made absolutely clear that the *raison d'être* of these public agencies [the government industrial laboratories] and their in-house programs is to assist industry, not replace it.[81]

Instead of proposing to restrict the "make-or-buy" policy, we strongly suggest its extension to all government scientific activities as defined by Statistics Canada, including technical surveys which are not covered by the present application of the contracting-out principle. The Canadian Chemical Producers Association rightly interpreted the Committee's intention when it stated:

> We see the main purposes of the proposed Canadian Industrial Laboratories Corporation as being:
>
> (a) The consolidation of government research so that any mission-oriented programs are less likely to outlive their usefulness.
>
> (b) Ensuring that R&D programs are relevant to industry needs and have industry financial support whenever warranted. If industry is unwilling to support a program, it must stand on an identified government need supported by the Minister of Industry, Trade and Commerce.[82]

Some organizations thought the intention of the recommendation was to remove all applied R&D programs from government departments and pass them to the Canadian Industrial Laboratories Corporation. That was not our intention. Others, such as the Alberta Society of Petroleum Geologists, view the setting up of the CILC as a further fragmentation of government efforts whereas the Committee sees the proposed corporation as a consolidation intended to prevent further fragmentation.

Again we want to emphasize that our proposal does not contemplate that CILC should carry out all in-house industrially-oriented R&D programs. For instance, it does not include applied research and development carried out on natural resources; more specifically, on non-renewable resources by the Department of Energy, Mines and Resources, on fisheries and forestry by the Department of the Environment, and on agriculture by the Department of Agriculture.

The activities of CILC would be restricted mainly to assistance to manufacturing industries. They would include the work done at present by NRC on what Dr. Steacie described as "specific industrial problems, short-term industrial problems (i.e. ad hoc investigations), investigations for the services, consulting, testing, specifications and miscellaneous inquiries." The forest products laboratories operated by the Department of the Environment and the metallurgical laboratories of the Department of Energy, Mines and Resources should be transferred to CILC. The Ministry of State for Science and Technology should determine whether other similar establishments such as the Food Research Institute pres-

ently located in the Department of Agriculture should also belong to CILC.

The Committee is convinced the Canadian Industrial Laboratories Corporation could become another coherent multi-purpose institution offering the advantages of specialization and integration; big enough to be viable, yet not too big to be manageable. It should be organized flexibly to meet the changing needs of industry. It should work in close co-operation with research councils in the provinces and with the engineering community in the universities and in the private sector as well as with its representative organizations. It should also be able to ensure more mobility of its R&D staff either between the areas of work or between government, industry, professional engineering firms, and universities.

To begin with the Canadian Industrial Laboratories Corporation would merely acquire existing capital equipment, facilities, and some staff already *within* the federal government establishment. Thus it would not involve more intramural R&D but the proper focussing, integration, and management of presently fragmented activities. It would break existing barriers and provide for cross-fertilization among experts sharing a similar motivation. Future expansion of the corporation's activities would depend on user demand.

Dr. Solandt, in his last report as chairman of the Science Council, came close to our recommendations for transforming NRC into an academy of basic research and creating a Crown industrial laboratories corporation:

> NRC's traditional strength has rested on the outstanding performance of a number of gifted basic researchers, who were given both the resources and the freedom to pursue their scientific interests in directions of their own choosing. While this has given Canada a strength in some areas of basic research, the administrative intermingling of applied research groups with the basic research groups, in an organization attuned to creating the conditions necessary for good basic research, has probably been a major factor in distracting the applied groups from their primary role of supporting industry. I would recommend, therefore, that the pure research groups in NRC be organized into an institute of pure research which would report to NRC's President and Council, but which would be administratively separate from the applied laboratories.[83]

While we feel sure Dr. Solandt is right in proposing to separate the two kinds of laboratories, he did not go far enough. Indeed, their top managements, including their chief executives and their boards, need to be quite different types of people with different skills and background. While the basic research laboratories need to be inspired and guided at the top by scientists of high reputation, the industrial laboratories require a top management with a demonstrated knowledge of industrial innovation and a board with strong representation from industry to make sure

that their activities will serve user needs effectively. All empirical studies show that this is an essential requirement for success.

The Committee cannot see how a single management in one institution could respond to two very different types of challenges and provide the proper guidance and working conditions required in each case. The experience of the Bell Telephone Laboratories in the United States further justifies the creation of a separate corporation for the government's industrial laboratories.

2. *A multi-purpose grant program for R&D in industry*

The Committee has recommended that all existing specific grants designed to encourage R&D activities in industry be integrated into one multi-purpose program, putting it under the management of the Department of Industry, Trade and Commerce, which has the federal responsibility for industrial development.

The Canadian Manufacturers Association did not respond positively to this recommendation because, in its view, there is excellent co-operation at present between industry and the departments and agencies supporting R&D activities. By contrast, the Electronic Industries Association of Canada said this proposal "is almost totally supported by the EIAC."[84] A major Canadian-owned company suggested this recommendation should be implemented immediately. The Association of Consulting Engineers of Canada declared:

> We strongly support the concept of Industry, Trade and Commerce administering all Government R and D incentives to the private sectors.[85]

On the whole, this recommendation has received wide support and it could be implemented with little effort. The Committee urges the government to do so. We also suggest that the Department of Industry, Trade and Commerce should carefully evaluate the program so as to establish the public benefit gained from this expenditure of public funds.

The experience of many countries is that industry should develop skills enabling it to use existing information rather than conduct R&D. Moreover, firms that have the ability to innovate, to successfully couple research with application, do not have to be persuaded through government grants to spend substantial fractions of their income on research. These two points were covered in Volume 2 by specific recommendations.

3. *Scientific and technical information, information dissemination and transfer, and technological forecasting*

The Committee made specific suggestions about the roles of the Ministry of State for Science and Technology and the Department of Industry, Trade and Commerce in the fields of STI, information dissemination and transfer, and technological forecasting.

A number of commentators observed that we had some notable strengths in the area of science. For example, the Alberta Society of Petroleum Geologists said Canada's information system in the earth sciences was in advance of anything in the Western world. Support for the Committee's recommendations was of a very general kind; organizations applauded the spirit of the recommendations without commenting in any detail. The Canadian Chemical Producers Association thought the recommendations would be improved if the creation of new services depended on demands from industry:

> While all the information gathering and disseminating agencies are intended to be in support of industrial innovation, there is no proposal for the direct involvement of industry.[86]

The Committee agrees that industry should be directly involved with the creation and operation of the new systems and services. We have suggested they should be organized in co-operation with the communication industry and "so as to encourage the development of a Canadian information and forecasting industry."[87]

We realize, however, that this is not enough. Industry at large, as the main user of these systems and services, should be directly involved in their management, to guarantee that they will respond quickly to specific needs. Donald A. Schon has stated that "information," "transfer," and "documentation" are merely luggage.[88] This may be true, but we suggest that having the proper luggage is quite important and that industry should have a direct role in its selection.

4. *Industrial task forces and the Office of Industrial Re-organization*

The Committee recommended that the Minister of Industry, Trade and Commerce ask secondary manufacturing industries to organize task forces, with appropriate labour representation, to consider the problems of scale and specialization and then prepare a plan to improve the efficiency, innovative capacity, and international competitiveness of individual firms through mergers and otherwise. To facilitate the work of

the task forces and a major industrial conversion plan, we also suggested the creation of an Office of Industrial Re-organization to be located in the Department of Industry, Trade and Commerce.

Some industrial associations felt past attempts at industry-government discussions had been characterized rather by frustration and delay than success. Government officials have mentioned the same experience. One large Canadian-owned international corporation said that on the basis of their experience the task forces could not operate efficiently. The company accepted the objectives of the task force, nevertheless, and agreed to co-operate in the development of any approach that seemed to have more chance of success. However, a senior executive of another major Canadian-owned corporation urged the rapid adoption of the Committee's industrial task force recommendations as a matter of the utmost urgency. The Pharmaceutical Manufacturers Association of Canada found the task force recommendations intriguing but cautioned that, in their view, more work would have to be done in thinking through the operational procedures. The Canadian Manufacturers Assocation made no detailed comment because of the government's declaration that it was working on a national industrial strategy but warned that any such task force should be voluntary.

The Electronic Industries Association of Canada rejected the proposals:

> Our opinion is that industry has an acute sensitivity to changes in the business environment and in market forces; in reacting to these changes industry has the capability to rationalize itself and effect appropriate mergers to meet its objectives. Government direction of such actions is not desirable.
>
> On the other hand the EIAC believes that a continuing dialogue with government is always useful and as the representative of a major industry it is, in common with other trade and business associations, pursuing discussions with government representatives on matters relating to industrial strategy, the scale and competitiveness of our industry and the necessary economic environment that will enable industry to reach its objectives. Following such discussions it is hoped that appropriate legislation will be enacted which would facilitate the kind of voluntary mergers and rationalizations envisaged by the Senate Committee as being desirable at this time.[89]

This plea to maintain the status quo and the suggestion that industry can cope with the problems by its own initiative appears to be unique and is strange when one considers the situation in other industrial countries. (Even in large industrial countries such as Japan mechanisms have been established for close government-industry co-operation simply for the sake of industrial survival.)

One factor that may cause industrial associations to react negatively to the recommendation is the presence of branch plants of foreign companies. We believe the managers of foreign subsidiaries would conclude, on

reflection, that industrial task forces would operate to their benefit. They should realize that as time goes on these subsidiaries in the manufacturing sector may well lose their *raison d'être* unless they cease to be mere replicas of their parent company and are allowed to specialize and compete on world markets. The Committee believes that through participation in the industrial task forces foreign subsidiaries would be assisted in finding new, innovative, and rewarding ways of improving their productivity which would make them more profitable and enable them to increase their contribution to the country's long-term interests. The role of the multinational corporation is being questioned in most countries today; if their subsidiaries cannot adjust better to the domestic environment of the host country they will contribute to the spreading of extremist feelings. This is already happening in Canada.

The Association of Consulting Engineers of Canada agreed with sector task forces but suggested that "government accomplish this by using consultant Task Forces, to study and report to industry and to Government on specific sector opportunities and problems, and to recommend incentive programs. This would give an efficient answer in a short time."[90]

The Canadian Chemical Producers Association wrote: "We agree that every effort should be made to achieve this set of recommendations."[91] Dr. Alexander King commented:

> The proposal to create task forces for the various industrial sectors is excellent, but of course their scope necessarily goes far beyond that of science policy, at least in the traditional sense. Throughout this section of the report, innovation is the dominant theme rather than research as such. I am sure this is right and that attention must be given to a whole variety of interests and functions, including banking and marketing in addition to the scientific and industrial base.[92]

On the whole, our concept of industrial task forces for the secondary manufacturing sector received broad support. The need for a major conversion in that sector has been universally recognized as urgent, and it was clear that something had to be done quickly and boldly. We suggested one way of tackling this complex problem. We are not absolutely wedded to the industrial task forces we described and suppose there may be better ways of achieving the same purpose, though none appeared in the comments we received.

We remain convinced, however, that three specific requirements must be met by any solution. First, the initiation of a major industrial conversion in the secondary manufacturing sector is the more urgent because it will take several years to complete and may, indeed, require a continuing operation. Secondly, whatever formula or mechanism is selected must place the main responsibility for preparing the conversion on industry itself, or it will fail. Thirdly, we should not expect industry to take the

initiative if the government is not ready to provide leadership, encouragement, and assistance.

This is why we now urge the Department of Industry, Trade and Commerce to create the Office of Industrial Re-organization. The office need not necessarily be organized along the lines suggested in Volume 2, especially if the concept of industrial task forces is not used. What matters is to establish the office properly so that it can play the role of catalyst for industry, act as a prime mover in inducing industrial managers to assume their responsibilities, and indicate to them that the government not only accepts the idea of a major conversion but is also ready to co-operate. We feel that until the office is created this important and urgent national operation will not be undertaken.

5. *The Interdepartmental Committee on Innovation*

The Canadian government must strengthen its positive impact on the industrial innovation process if industrial re-organization is to succeed. In Chapter 16 of Volume 2 we mentioned several ways in which the government actually deterred industry from improving its capacity to innovate and impeded the innovation process itself. To remove these impediments and improve the public climate in which industry has to operate, we recommended that the scope, composition, and authority of the Interdepartmental Committee on Innovation be enlarged so that, working with the departments and agencies concerned, it could appraise the implications of their decisions and policies for the innovative process. We included some specific suggestions about the role of the Minister of State for Science and Technology.

Strong support for this recommendation was implicit in many of the briefs commenting on Volume 2. They pointed to several government policies that had a negative impact on innovation in the private sector. The Electronic Industries Association of Canada commented that our recommendation was "almost totally supported by the EIAC."[93]

The Committee is concerned that the Interdepartmental Committee on Innovation has not adequately responded to the challenge implicit in our recommendation. We believe the Ministry of State for Science and Technology should take the initiative here and seek the support of the Department of Industry, Trade and Commerce in convincing the Cabinet that effective action should be launched soon on this crucial front.

The Committee recommended the creation of an institution called the Canadian Innovation Bank to support the launching of industrial innovations. Although the CIB was intended to assist new or small companies, some large Canadian companies gave this recommendation strong support. One large, high-technology, Canadian-owned company commented that "this is perhaps the best recommendation in the report."[94] The senior vice-president of another large Canadian-owned company declared, "We urge rapid adoption of this recommendation."

The Canadian Electrical Manufacturers Association expressed substantial agreement with this proposal. The Canadian Manufacturers Association indicated that the recommendation had merit but suggested that "a thorough review, preferably by means of another Senate Committee study, be carried out on the needs and problems of individual inventors and small industries."[95] The Electronic Industries Association of Canada said the recommendation was "almost totally supported" but questioned why the functions foreseen for the Canadian Innovation Bank could not be carried out by the Industrial Development Bank or the Canadian Development Corporation.[96] The Association of Professional Engineers of Ontario also supported the recommendation in principle but like the EIAC suggested that the IDB, suitably developed, could fulfill the functions of the proposed CIB. On the other hand, the Association of Consulting Engineers of Canada was afraid that the Canadian Innovation Bank "might slip into the same conservative stance as the Industrial Development Bank."[97]

The Committee is more convinced than ever that there is a great need for public support—in terms of loans, equity capital, and managerial services—for the launching of innovations. Since the publication of Volume 2 we have received many requests from individual inventors and small would-be-innovative companies for venture capital in one form or another. In several cases they had received offers of capital assistance from American companies which they could not match in Canada.

This situation must be remedied if our country is to reduce its export of ideas and import of new technology. The Canadian Development Corporaticn cannot fill the gap; it already has a major mission to accomplish. We have also noted with interest that the CDC has begun to invest in private companies in the venture capital business, a most desirable and appropriate initiative. In our view, however, it should not directly enter the venture capital business itself. To do so it would have to develop the special skills and employ the additional staff that a new agency would have to acquire, so that the extension of its activities would not represent a saving of financial and manpower resources. More seriously, this would require the CDC to stop helping existing private

venture capital companies—a role that is highly desirable—to avoid an obvious conflict of interest.

The Committee has noted a statement on small business by the Hon. Alastair Gillespie, Minister of Industry, Trade and Commerce, in the House of Commons on July 11, 1973. The announcement declared the government's intention of establishing an independent Crown corporation to be called the Industrial Bank and Development Agency for smaller and medium-sized enterprises. It will report through the Department of Industry, Trade and Commerce.

While the government proposes "to build upon the existing strengths and organizational network of the IDB," it expects that the new agency will "make greater use of its authority to provide equity financing, especially where such financing could contribute to a sounder financial structure of an enterprise or where it would facilitate financing from commercial sources." In addition, the IBDA "will have services available to assist small businessmen in both management counselling and management training by taking over and expanding several existing programs in this area. . . ."[98] The new agency will also provide regional information about other government assistance programs including R&D grants to industry.

The mission of the new agency will be similar to what we envisaged for the Canadian Innovation Bank. The Committee proposed a new institution because it was convinced the Industrial Development Bank, with its present status, limited services, and lack of dynamic policies, could not fill the gap properly and efficiently. The government has come to the same conclusion. Among its priorities, we feel, the new agency should include encouragement of promising innovations; and we hope it will not inherit the reluctant and passive attitude of IDB. We intend to have a careful look at the legislation when it is introduced by the government, to see if it meets these requirements.

7. *Assistance to small inventors*

We also agree with the Canadian Manufacturers Association that it is essential to consider "the needs and problems of individual inventors." We realize that few inventors are likely to be successful or even working on practicable inventions, and that only a small number of inventions may ever be associated with innovation. During its travels, the Committee talked to successful research directors holding dozens of patents, none of which had ever borne fruit. Nevertheless, during the last five years the Committee has had many occasions to observe the inhuman and overly bureaucratic manner in which individual inventors are treated by government departments and agencies. To put it bluntly, they are

given the run-around, they are sometimes insulted, and their motives are questioned. Some leave the country, others sell their inventions, seek assistance abroad, or become discouraged and give up. The Committee believes this negative treatment has to stop. The country can ill afford to ignore this possible source of national wealth.

The Committee was impressed by the greater care the Swedish government shows in dealing with inventors. It has a scheme to assist inventors which enables them to work full-time for a year on an invention. The United States, under the spur of its current concern for its lagging civilian technology and its international balance of trade, is actively seeking means of promoting inventions and serving its individual inventors more effectively. New arrangements have been made allowing federal government laboratories, under certain specific restrictions, to proof-test inventors' ideas. There is also a National Inventors Council to advise them.

The only Canadian government assistance we have heard of was a grant received by Innovation Quebec, a private group established to give free advice to potential small inventors. The grant was provided under the Local Initiatives Program. It is our understanding that while there were some failings mainly because of the restrictions imposed by that program, the experience of Innovation Quebec was successful enough to demonstrate the concept's interest. The Committee believes it would be valuable for the Department of Industry, Trade and Commerce to make a detailed case history of this experiment, including an evaluation of the cost/benefit of the public monies expended. We are convinced this concept could be applied to other Canadian regions as a special program supported by the department.

The Committee therefore recommends that the Department of Industry, Trade and Commerce set up a task force to investigate all factors having an important effect on the individual private inventor in Canada, to consider the kind of public assistance provided by other countries in this area, and the desirability of establishing a Canadian inventors council to assist private inventors and to act as their formal spokesman.

SCITEC could be asked to undertake this study. In any case, it should be clearly understood that the task force should include *successful* Canadian inventors and innovators.

8. *Recognition of innovation and invention*

Canada gives a wide range of awards to individuals who distinguish themselves in the arts, letters, and sciences as well as in public service,

and Canadians also receive international awards in these areas. Little formal distinction is given to those who help us "pay our way" as a nation, though. The Committee believes this gap should be filled with some formal recognition of people who launch successful innovations.

Other countries have instituted special awards for successful innovators, for example Britain where, each year, the Queen's Awards to Industry are presented. A committee under the chairmanship of the Duke of Edinburgh seeks outstanding achievements by British industry either in increasing exports or in technological innovation.[99] The emphasis is on the *use* of new technology rather than discovery or invention.

The report of the committee which drew up the scheme gives eight criteria for awards, of which six cover export achievement. The other two relate to technological innovation:

> (vii) A significant advance in the application of advanced technology to a production or development process in British industry. Recognition should only be accorded under this head if greater efficiency results from the process.
>
> (viii) The production for sale of goods which incorporate new and advanced technological qualities.[100]

In 1973, there were 83 awards—66 for export achievement, 15 for technological innovation, and 2 for achievement under both criteria.

The Queen's Award to Industry differs from personal honours in that it is given to an industrial unit—management and employees working as a team. It is akin to the "battle honour" given to a military unit. Units holding it are entitled to fly the award flag and use the emblem on their letter headings, in advertising, on the packaging of goods produced in Britain, on the goods themselves, and on articles worn by employees such as lapel badges and neckties.

The Committee believes that similar recognition should be given to groups in Canada which have been successful technological innovators, especially those contributing to substantial exports. This system would draw special attention to the need for improvement in Canadian innovative performance. It should be extended to include significant inventions which would then become better known to Canadian innovators and investors. In this way, we might reduce our exports of ideas.

The Committee therefore recommends:

1. That the government institute a series of awards to be given to Canadian industrial units for meritorious technological innovation and to Canadians contributing significant inventions, to be called The Innovation Canada Award and the Invention Canada Award; and

2. That the Ministry of State for Science and Technology and the Department of Industry, Trade and Commerce jointly advise on the nature of the awards and the criteria and process of selection.

THE REORGANIZATION OF THE DEPARTMENT OF INDUSTRY, TRADE AND COMMERCE

The reorganization plan proposed by the Committee involves highly specialized and integrated agencies. It provides for new institutions designed to encourage the various stages of the innovation process. Under this proposal the Department of Industry, Trade and Commerce would be more clearly charged with the responsibility for implementing a realistic technological and industrial strategy.

If our proposals are accepted, the department would have the main government tools and services to improve the innovative capacity of industry, with the exception of the R&D procurement policy which is assigned to the Department of Supply and Services. Through its Office of Industrial Reorganization, it would be expected to initiate the industrial conversion needed in many manufacturing sectors to increase the size of firms and provide a more appropriate R&D basis. Through an integrated, multi-purpose grant system, it would be better able to sustain industries' R&D performance. The Canadian Industrial Laboratories Corporation would complement these scientific activities and respond to specific industrial needs. The technological information system would make individual firms and industries aware of developments at home and abroad so that they could profit from these new opportunities and avoid the waste of duplicating scientific activities carried out elsewhere. The new Industrial Bank and Development Agency would provide loans, equity capital, and management services to smaller firms and individual inventors to help them launch innovations.

The supply of all these services integrated into the Department of Industry, Trade and Commerce would substantially improve the innovative climate in industry. It would also give the department major new responsibilities and require a reorganization at the top, a new division of labour that would permit efficiency and dynamism in the performance of existing and new services without overburdening senior officers.

The Committee does not believe it would be wise to divide the department as it was in 1963. It is important for domestic technological and industrial strategy to be directly related to trade policy and indeed to help define it. It seems, however, that the fusion of the two former departments in 1969 has not had this result. The trade mission of the new department has been maintained at the expense of the industrial one which, in the Committee's opinion, is most regrettable.

It is urgent to correct this situation. We are aware that the department's trade mission will increase in importance and require more attention in the future. The international negotiations beginning in Tokyo will be long, complicated, and crucial for Canada. Our bilateral discussions with the United States will also have a determining impact on our country's long-term future. External trade will continue to be vital for Canada's prosperity and growth. In these matters, we cannot go it alone; we must emphasize the multilateral approach. But given emerging world trends, we must also recognize its limitations and be prepared to develop a special partnership with the United States designed to ensure our own long-term economic viability. Canada has reached new crossroads in matters of trade and the Department of Industry, Trade and Commerce's mission must be discharged with efficiency and imagination.

The success of the mission, however, largely depends on our success in launching a bold technological and industrial strategy. The contribution of our trade policy to sustaining the national economy will necessarily be limited if Canadian goods, specially manufactured products, are not competitive on domestic and world markets. In this perspective the department's industrial mission appears crucial. We believe this second mission can be accomplished efficiently, provided it receives proper support and leadership. We are equally convinced that a single management at the top cannot give the attention and care required by these two important missions. Thus, although they should remain under the same ministerial roof, they should be separated for administrative purposes.

The Committee therefore recommends that a deputy minister of industry be appointed in the Department of Industry, Trade and Commerce as the senior official responsible for implementing a technological and industrial strategy and for administering its support services, and that a senior assistant deputy minister for technology and innovation be designated as soon as possible to serve eventually under the new deputy minister when appropriate legislation has been approved.

This senior official should have a practical knowledge of Canadian industry and of the requirements for the successful introduction of new technology and industrial innovations. He should be supported by adequate staff and work in close collaboration with the deputy minister of trade and commerce. The department will be able to pursue its two important missions effectively only if it is reorganized and strengthened along the lines we have suggested.

CONCLUSION

The organization proposed by the Committee is not complete. It deals with the administrative structures of the central machinery within the

framework of the concerted action model; the institutions responsible for carrying out intramural basic research and for government support of this scientific activity in universities and other organizations; and the government services required to assist industrial conversion, R&D activities, and innovation. (Organization of the interfaces of science policy is covered in the next chapter.)

Our plan does not include reorganization of the federal government's intramural scientific activities related to social innovations and natural resources. But we believe, for instance, that MOSST should undertake a careful review of existing government establishments responsible for scientific programs in the area of renewable resources, such as forestry, fisheries and agriculture. There is always a danger of overlapping in these activities. To minimize it, the review should consider integrating the specialized agencies presently located in Environment Canada and the Department of Agriculture or perhaps redefining their roles more precisely.

Our proposed reorganization, however, incomplete as it is, stands by itself and covers the areas where change is most urgently needed. It provides for a coherent arrangement with greater specialization or integration as required. Moreover, the terms of reference proposed for MOSST guarantee that the government reorganization of scientific activities will not only be extended to areas not specifically covered by the Committee but will also continue to be pursued. The need for a continuing review of administrative structures and mechanisms has been indicated by Theodore J. Lowi:

> Modern man has a genius for contriving efficient, productive institutions. But inevitably institutions betray him; no institution will ever fulfill all his needs. . . . Success in one era merely renders institutions incapable of processing adequately the demands of the next era. . . .The disorder that accompanies the failure of institutions is certainly not comfortable. . . . [But] there is a positive side to institutional atrophy. . . . The weakening of institutions can open up a recycling of opportunities.[101]

We recognize the process of institutional atrophy. We believe the present government organization for science, technology, and innovation is "incapable of processing adequately the demands of the next era." We consider the plan we have suggested a much better arrangement for the 1970s but we perceive it only as a phase of the endless "recycling of opportunities."

Even within that perspective we are conscious of the fact that our recommendations calling for organizational change meet strong resistance from agencies that would be disrupted by them. Organizations are not often built to be flexible and adaptable. Social systems have a natural

inclination to interpret change as a threat and to develop defence mechanisms. Donald A. Schon has described them:

> An oversimplified first response to the presence of a threat is to ignore it, a response for which Sullivan used the phrase "selective inattention." . . .
>
> When it is no longer possible to avoid noticing a threat, it may be possible to launch a counter-attack or even a preventive attack before the threat has materialized. . . .
>
> When processes embodying threat cannot be repelled, ignored, contained or transformed, social systems tend to respond by change—but by the *least change* capable of neutralizing or meeting the intrusive process. . . .
>
> In all these cases, the response is similar—minimal compliance with the demand for change. It is particularly effective where those pressing for change cannot distinguish significant from token compliance, or can muster their forces only for an initial assault. In this respect, established social systems have the advantage; they are able to exert continuing energy in the service of their stable state, whereas those attacking can seldom sustain their attacks.[102]

The reactions of most departments and agencies to the reorganization proposals of Volume 2 have been manifestations of "dynamic conservatism," of a tendency to fight to remain the same.[103] Some of them were met by "selective inattention." In other instances the response combined counter-attack and minimal compliance. Some agencies were "able to exert continuing energy in the service of their stable state" in the hope that the Committee or the government would not be able to sustain its effort to bring about change. In a few cases we have seen the beginnings of organizational in-fighting over territory, which is not surprising since "the relationship of agencies to one another is best characterized as a conflict of rival baronies, each jealously guarding its own territory and seeking to expand that territory at the expense of other agencies."[104] All these reactions were to be expected: they are inherent in most human institutions and reflect a natural desire to preserve the stable state.

The government, however, must sustain its efforts against this natural desire. Most of the recommendations in Volume 2 have received a significant degree of support from the scientific, engineering, and industrial community. The case made by our critics rests mainly on belief in the unbroken-spectrum theory of innovation. The additional evidence introduced in this chapter should convince the impartial observer that the theory is invalid as a general proposition and that the time has come to abandon this aging myth. We have also tried to define some proposals more exactly and to justify them more fully. With this additional evidence and justification, we are convinced that the package offered in Volume 2 will be more widely accepted today than it was when first presented. The Canadian government should now accept it and implement it as soon as possible.

NOTES AND REFERENCES

1. Lord Rothschild, *A Framework for Government Research and Development*, London, H.M.S.O., November, 1971, p. 3.
2. Ibid., p. 4.
3. Jeff Carruthers, "Sensationalism at the NRC, or should the pot call the kettle black?", *Science Forum*, February, 1973.
4. Ibid., p. 38.
5. Brief to The Minister of State for Science and Technology and to the Senate Special Committee on Science Policy by The Association of Consulting Engineers of Canada, pp. 5-6.
6. Comments on Volume 2 of Report of Senate Special Committee on Science Policy by the Electronic Industries Association of Canada, 77 Metcalfe St., Ottawa, Canada, October, 1972, p. 2.
7. The SCITEC Forum on Science Policy, Position Paper, December 13, 1972, p. 1.
8. Philip Gummett and Roger Williams, "Assessing the Committee for Scientific Policy", *Nature*, Vol. 240, December 8, 1972, pp. 329-332.
9. C. West Churchman, *The Design of Inquiring Systems; Basic Concepts of Systems and Organization*, Basic Books Inc., London, 1971.
10. *Targets and Strategies for the Seventies, op. cit.*, p. 389.
11. Stephen Toulmin, *Human Understanding*, Volume 1: General Introduction and Part 1, Clarendon Press, Oxford, 1972, pp. 377-378.
12. The Centre for the Study of Industrial Innovation, "Success and Failure in industrial Innovation", London, 1972, p. 28.
13. Erik A. Haeffner, "The Innovation Process", *Technology Review*, March/April, 1973, pp. 18-25.
14. Ibid., pp. 19-20.
15. J. Langrish, M. Gibbons, W. G. Evans and F. R. Jevons, *Wealth from Knowledge: Studies of Innovation in Industry*, MacMillan, London, 1972.
16. Ibid., p. xi.
17. Ibid., p. xii.
18. Ibid., p. 41.
19. Ibid., p. 40.
20. J. Herbert Holloman quoted by D. S. Greenberg, *The Politics of Pure Science*, New American Library, New York, 1967, pp. 32-33. Greenberg points out that "The cult of research, pure and otherwise, holds forth research as the solution for many social ills that, in fact, have little or nothing to do with lack of knowledge (footnote p. 33)."
21. Langrish *et al., op. cit.*, p. 42.
22. Ibid., p. 76.
23. K. Oshima, "Technological Innovation in Japan", *International Aspects of Technological Innovation*, Science Policy Studies and Documents No. 26, Unesco, Paris, 1971, pp. 57-61.
24. Ibid.
25. Ibid.
26. Ibid.
27. Charles T. Stewart, "A Summary of the State-of-the-Art on the Relationship Between R&D and Economic Growth/Productivity", in *A Review of the Relationship Between Research and Development and Economic Growth/Productivity*, National Science Foundation, February, 1971, pp. 18-19.
28. Donald V. Fowke, "The Management of Uncertainty", *Cost and Management*, January-February, 1970, pp. 46-47.
29. *Targets and Strategies for the Seventies, op. cit.*, p. 439.
30. Science Council of Canada, Annual Report, 1971-72, p. 51.
31. C. H. Townes, "Differentiation among research laboratories", *Daedalus*, Spring 1973, p. 164.

31a. *Notes for a presentation to the AUCC Commission to study the Rationalization of Research in Canadian Universities* by the Executive Committee of the Humanities Research Council of Canada, 8 February 1972, p. 16.

31b. The Social Science Research Council of Canada, the Response to a Science Policy for Canada, Report of the Senate Special Committee on Science Policy, Volume 2, October 3, 1972.

32. *Targets and Strategies for the Seventies, op. cit.*, p. 436.
33. Science Council of Canada, Annual Report, 1971-72, p. 50.

34. Response to the Report of the Senate Special Committee on Science Policy, Volume 2—Targets and Strategies for the 70's, by The Association of Professional Engineers of the Province of Ontario, Appendix 'A', p. 1.
35. *Targets and Strategies for the Seventies, op. cit.*, p. 522.
36. SCITEC Forum on Science Policy, Workshop 2, "Basic Research and the Foundations", p. 1.
37. Comments on Report of the Senate Special Committee on Science Policy, Volume 2, by The Canadian Manufacturers' Association, October 20, 1972, p. 5.
38. Ibid.
39. Science Council of Canada, Annual Report, 1971-72, p. 51.
40. *The Future of the Research Council System,* Report of a C.S.P. Working Group under the Chairmanship of Sir Frederick Dainton, 1971, p. 15.
41. *Targets and Strategies for the Seventies, op. cit.*, p. 439.
42. SCITEC Forum on Science Policy, Workshop 2, *op. cit.*, p. 1.
43. The Response of the Social Science Research Council of Canada to Report of the Senate Special Committee on Science Policy, Volume 2, p. 6.
44. *The Future of the Research Council System, op. cit.*, p. 15.
45. *The Future of the Research Council System op. cit.* p. 7.
46. Rothschild, *op. cit.*, p. 13.
47. *Targets and Strategies for the Seventies, op. cit.*, p. 467.
48. Alexander King, "The Lamontagne Report: An Erudite Approach to Science Policy Problems", *Science Forum*, April, 1972, p. 7.
49. SCITEC Forum on Science Policy, Position Paper, December 13, 1972, p. 2.
50. The Canadian Chemical Producers' Association, Comments on Recommendations contained in Report of the Senate Special Committee on Science Policy, October, 1972, p. 5.
51. A Response of The Pharmaceutical Manufacturers Association of Canada to the report of the Special Committee (Lamontagne) on Science Policy of the Senate of Canada, October, 1972, p. 14.
52. Brief to The Minister of State for Science and Technology and to The Senate Special Committee on Science Policy on The Report of the Senate Special Committee on Science Policy by The Association of Consulting Engineers of Canada, October, 1972.
53. Response to the report of the Senate Special Committee on Science Policy, Volume 2, by the Alberta Society of Petroleum Geologists, Ocotber 30, 1972. p. 9.
54. Response to the Report by The Association of Professional Engineers of the Province of Ontario, Appendix 'A', *op. cit.*, pp. 2-3.
55. "SCITEC Response to Volume 2 of Senate Science Report as of March 15th, 1972: Summary Report", contained in *SCITEC IV*, Proceedings of Annual SCITEC Conference held in Ottawa, February 25, 26, 1972, pp. 68-84.
56. Quoted by the Science Council, Report No. 4, *Towards a National Science Policy for Canada,* October 1968, p. 25.
57. Howard M. Vollmer, "Basic and Applied Research", *The Social Contexts of Research,* John Wiley and Sons, Toronto, 1972, p. 92.
58. Harvey Brooks, "Knowledge and Action: The Dilemma of Science Policy in the '70's", *Daedalus*, Spring 1973, p. 137.
59. J. A. Morton, "From Research to Technology", *The R&D Game*, edited by David Allison, M.I.T. Press, 1969.
60. Ibid., p. 219.
61. Ibid., pp. 224-225.
62. Donald Fleming, "Emigré Physicists and the Biological Revolution", in *Perspectives in American History*. II (1968), pp. 152-189. And also the essays by G. S. Stent, R. Olby, and L. Pauling, in *Daedalus*, Autumn, 1970, pp. 882-1014.
63. From editorial foreword of *Vigilance and Attention: A Signal Detection Approach*, by Jane F. Mackworth, Penguin Books, 1970, p. 9.
64. Ibid.,
65. Gabor Strasser, "What is in Store for our Scientific Technological Establishment". *Science Policy Reviews*, Vol. 4, No. 4, 1971, p. 6.
66. Nicholas Georgescu-Roegen, *The Entropy Law and The Economic Process*, Harvard University Press, Cambridge, 1971.
67. "Optimal control: A mathematical supertool", *Business Week*, May 19, 1973, p. 76. See also, *Optimal Planning for Economic Stabilization*, published by the North-Holland Publishing Co. of Amsterdam.

68. Ibid., p. 74.
69. Ibid.
70. Alexander King, "The Lamontagne Report: An Erudite Approach to Science Policy Problems," *op. cit.*, p. 7.
71. Ibid., pp. 6-7.
72. House of Commons Special Committee on the Operations of the National Research Council, June 15, 1950, p. 130.
73. *Science in Canada*, Selections from the speeches of E.W.R. Steacie edited by J. D. Babbitt, University of Toronto Press, 1965, p. 121.
74. Ibid., p. 128.
75. "New International Group will study global problems," *Physics today*, Vol. 2, Feb. 1973, pp. 69-70.
76. *Targets and Strategies for the Seventies*, *op. cit.*, p. 590.
77. Alexander King, "The Lamontagne Report: An Erudite Approach to Science Policy Problems", *op. cit.*, p. 8.
78. Comments on Volume 2 by The Canadian Manufacturers' Association, *op. cit.*, p. 17.
79. A Response of the Pharmaceutical Manufacturers Association of Canada, *op. cit.*, p. 15.
80. *Targets and Strategies for the Seventies*, *op. cit.*, p. 589.
81. Ibid., p. 588.
82. The Canadian Chemical Producers' Association, Comments on Recommendations . . . , *op. cit.*, p. 9.
83. Science Council of Canada, *Annual Report 1971-72*, pp. 46-47.
84. Electronic Industries Association of Canada, Comments on Volume 2 of Report of Senate Special Committee on Science Policy, p. 11.
85. Brief on the Report of the Senate Special Committee on Science Policy by The Association of Consulting Engineers of Canada, *op. cit.*, no. 9b.
86. The Canadian Chemical Producers' Association, Comments on Recommendations . . . , *op. cit.*, p. 10.
87. *Targets and Strategies for the Seventies*, *op. cit.*, p. 593.
88. Donald A. Schon, *Beyond the Stable State*, Temple Smith, London, 1971.
89. Comments on Volume 2 by the Electronic Industries Association of Canada, *op. cit.*, p. 8.
90. Association of Consulting Engineers of Canada, Brief on the Report of the Senate Special Committee on Science Policy, *op. cit.*, no. 12.
91. The Canadian Chemical Producers' Association, Comments on Recommendations . . . , *op. cit.*, p. 5.
92. Alexander King, "The Lamontagne report: an erudite approach to science policy problems" *op. cit.*, p. 8.
93. Electronic Industries Association of Canada, Comments on Volume 2, *op. cit.*, p. 11.
94. Comments on Lamontagne Report Vol. 2 Science Policy. Bell-Northern Research, 13 October 1972.
95. Comments on Volume 2 by The Canadian Manufacturers' Association, *op. cit.*
96. Electronic Industries Association of Canada. Comments on Volume 2, *op. cit.*
97. Association of Consulting Engineers of Canada, Brief on the Report of the Senate Special Committee on Science Policy, *op. cit.*
98. *House of Commons Debates*, July 11, 1973, p. 5492.
99. Ibid., p. 5497.
100. *The Queen's Award to Industry* (H.M.S.O.), London, 1965.
101. Theodore J. Lowi, *The Politics of Disorder*, Basic Books, New York, 1971, pp. ix-x.
102. Donald A. Schon. *Beyond the Stable State*, Temple Smith, London, 1971, pp. 48-50.
103. Ibid., p. 31f.
104. Ibid., p. 165.

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THE INTERFACES OF SCIENCE POLICY

Science policy raises problems of relations between many institutions: the federal government and the provinces; the Canadian government, international organizations, and foreign governments; the Canadian scientific and technological community and others responsible for innovation; the Canadian Parliament and other parliamentary institutions. For a coherent and effective science policy, relations between these various institutions must be continuing and sound, and, if they are to be fruitful, the basic nature of science policy must be understood by all involved. The purpose of this chapter is to examine aspects of the interfaces.

FEDERAL-PROVINCIAL RELATIONS

According to our constitutional arrangements, science policy is an area of joint responsibility between the central government and the provinces. This raises issues of some complexity, which will increase as governments' involvement in social innovation develops and is seen to be an essential ingredient of science policy.

Although the constitution does not contain any specific reference to scientific activities, it cannot be denied that the Canadian government has a constitutional responsibility in this area. It is obvious, for instance, that it has the right to initiate such activities for the purpose of serving the policy missions assigned to it. But its jurisdiction, based on its wide spending power, goes further. Its overall competence on science policy issues was recognized by Marcel Faribault, who was well known for his constitutional interpretation in favour of provincial autonomy. He stated in 1956:

> Yet, research is not a teaching activity, properly speaking. It is well located in universities, but from a constitutional as well as from an accounting point of view, it ought to be financed by those who benefit from research, not immediately the students, but the professions, the industries and the governments, especially the federal government. It is, therefore, entirely proper for the federal government to finance scientific research to the fullest extent possible and I do not think any constitutional problem lies there, provided it be done on an individual grant basis as in the past with the National Research Council or, more and more, on a contract basis with the universities.[1]

However, the wide powers of the Canadian government do not restrict those of the provinces. Indeed, it can be claimed that provincial governments have a parallel jurisdiction.

Thus, under our present constitutional arrangements, scientific activities are an area of joint responsibility. This situation has not as yet created any serious difficulty because the Canadian government has been practically alone in exercising its jurisdiction in this field. Recently, however, some of the provincial governments have begun to develop an interest in science policy, and their involvement will gain momentum as urban and pollution problems increase and the costs and effectiveness of health care and education systems are subjected to more intense questioning.

The increasing interest of provinces in science policy is most desirable. Undoubtedly they should and will develop their own approaches in this area. It is beyond the Committee's terms of reference to instruct them, but we would like to offer two suggestions before they proceed too far in establishing their own policies. First, they could consider carefully how the Canadian government has developed its approach to science and technology in the past so as not to repeat the same mistake! Secondly, they might make a detailed survey of the activities and programs they already carry out; we recommend the approach the Committee has followed in its investigation of the federal scene. In collecting data describing their scientific activities, we hope the provinces will follow the definitions and apply the methods used by Statistics Canada. It would be to everyone's benefit to have provincial figures in a form directly comparable to federal statistics and to figures gathered by other countries.

Increasing provincial involvement in science policy will open a new area of federal-provincial relations. It will be crucial for the country as a whole and the scientific and engineering community in particular that these relations be formally established at an early stage and be conducted in an atmosphere of close co-operation rather than confrontation. Otherwise there is a serious danger that our small national scientific effort will become more unfocused and eroded by duplication, waste, and ineffi-

ciency. More importantly, there is the danger that our already weak innovative capacity will become even weaker.

The potential for involvement in scientific activities differs substantially from province to province. The larger provinces may want to initiate programs of their own while smaller ones, lacking the financial and manpower capacity, will expect the Canadian government to carry out their programs for them, thus raising the threat of undesirable duplication between the federal activities in the smaller provinces and the programs implemented by the larger provinces. These dangers will also exist at the interprovincial level if several provinces decide to launch similar programs when one would suffice. They are made all the more critical because of the vastness of this subcontinental country. We often speak of Canada's size but seldom fully appreciate its extent, or do much to overcome the unavoidable communication problems that result. From histories of the industrial revolution and studies of the innovation process we know of two critical requirements: the friendly and frequent co-operation of highly motivated, spirited people with complementary skills and a common goal, and a sharp, realistic appreciation of specific social needs.

The Committee hopes that flexible compromises between decentralized needs and the desirability of co-ordinated and coherent R&D programs undertaken at the proper scale will inspire the building of an industrial R&D and innovative ability in Canada, the development of social innovations, and our smooth entry into the post-industrial revolution.

Several steps should be taken to develop flexible federal-provincial arrangements. First, the four Atlantic provinces and four Western provinces could co-operate in developing their science policies and strive to make as large an area common as practicable. This would undoubtedly strengthen the financial and manpower capacity of these regions and enable them to develop a more adequate scientific and engineering effort.

Secondly, the provinces or the four main Canadian regions should not succumb to the temptation of empire building as they develop their science policies. They should shape their scientific effort only to meet specific real needs that cannot be satisfied otherwise. In this way the Canadian government would continue to have the main responsibility for science policy, in spite of a significantly improved participation at the provincial or regional level.

Thirdly, as a corollary, these arrangements would require better and more continuous consultations by the Canadian government with the provinces on science policy issues, the need to include regional needs in its priorities, and a meaningful attempt to decentralize its scientific establishments to the regions. To attain these objectives, federal-provincial relations in the area of science policy should be institutionalized.

The Committee therefore recommends that an Interministerial Federal-Provincial Committee on Science and Technology be established to meet at least once a year before the federal annual estimates for scientific activities are finally approved and to be presided over by the Minister of State for Science and Technology.

We believe such a committee should be established as soon as possible, before the provinces are committed to fixed positions and before the reorganization of federal agencies dealing with science and technology is finalized. With the new role we have proposed, the Minister of State for Science and Technology would have sufficient authority to carry out meaningful consultations with the provinces and regionalize federal priorities and scientific establishments. The minister should also make sure that federal departments and agencies involved in science and technology, including the Science Council and the proposed Canadian Industrial Laboratories Corporation, work in close collaboration with similar provincial institutions where they exist.

Fourthly, there is a new and important area of science policy that will require special attention and planning at the federal-provincial and interprovincial levels. This is science policy for social innovations and the improvement of our social systems, the second generation of science policy, as we have called it. At the end of Volume 2, we stated: "We feel that the national effort in this area should be substantially increased because of past neglect and the urgent need to improve the efficiency and control the rising costs of our social systems in such sectors as health care, pollution abatement, education, social security, housing and urban living, crime prevention, and criminal rehabilitation."[2]

Innovations in social policy and public welfare have usually occurred in a haphazard way and on the spur of the moment. They have too often been badly designed, costly, ineffective, and improperly evaluated. They face special impediments when new technology is introduced because they are subject to the rigidities of the public market and to the resistance to change offered by those who supply public services.[3] The Committee believes that many obstacles to innovation in social areas could be removed by adequate R&D programs if the innovation process were properly understood.

Given our system, most economic innovations have to be introduced by private firms through the ordinary market mechanism. In contrast, social innovations must often be launched by governments through legislation or administrative decisions. Moreover, the constitution puts many important areas of social policy, such as education, health care, and urban affairs, under provincial jurisdiction, although the Canadian government has been able to intervene through the use of its wide spending power.

These constitutional provisions raise some distinctive problems. It is obvious that the provinces and the Canadian government must build up an R&D capacity in the areas for which they are responsible. But it would be a waste of scarce funds and manpower if each provincial government were to aim for self-sufficiency and launch overall R&D programs of their own to meet all their requirements. There are major areas where the provinces have common research needs, specially in the field of social technology and indicators. On the other hand, it would be undesirable to ask the Canadian government to define and meet these common needs.

The R&D requirements associated with social innovation should directly involve ministers representing the two levels of government and be met whenever possible, by a national social research and development institute, which would be neither purely federal nor provincial. (We here use the expression "social R&D" in its widest sense to cover engineering involving the development of new technology and multi-disciplinary efforts designed to improve our social systems and the quality of life.) It would have a board representing the main R&D performance sectors. Whenever desirable, it would be expected to contract out major portions of its R&D programs to federal and provincial agencies as well as to universities and industry.

The Committee has noted the creation of the Institute for Research on Public Policy proposed by Ronald S. Ritchie, who has become its chairman. The letters patent of the institute declare:

> The objects for which incorporation of the proposed corporation is sought are:
>
> (a) to initiate, carry on, conduct, supervise and generally foster programs of research either within the corporation or by letting contracts, or both;
>
> (b) to provide research services or other facilities for institutions, corporations, agencies and individuals, including departments and agencies of Canadian governments at the federal, provincial, regional, and municipal levels, on such terms and conditions as may be mutually agreed between the corporation and its clients, provided that the research is in furtherance of these objects;
>
> (c) to undertake programs for the information of the public, of officials of governments, elected and appointed, and of policy makers in general;
>
> (d) to sponsor or organize conferences, meetings, seminars and training programs on matters of public or governmental interest or concern.

Ritchie included in his report (*An Institute for Research on Public Policy*)[4] an appendix entitled "Thoughts for Consideration by the Governing Body of an Institute for Research on Public Policy in Canada." This is reproduced as an appendix to this chapter.

The Committee agrees with most of the thoughts expressed on the role and operation of the institute. It is important, for example, for the institute to concentrate on medium and long term problems rather than

on current controversial situations, and on studies relevant to Canadian situations and needs rather than merely "to add to the general fund of theoretical knowledge."[5] We also agree that while its mandate should be wide, the institute should first concentrate on a few major programs. Ritchie mentions "regional economic disparity, the quality of the environment, the problems of native peoples, the determinants of productivity and growth (research, technology, education, and investment) and the complex of problems involved in urbanization. . . ."[6]

The Committee would like to offer some suggestions that might improve the role and operation of the institute. We believe this agency has been conceived as having too independent a role, in which it would be completely free to decide its priorities and research programs. While this would enable the institute to inform the public on issues and problems that appear important to it there is a serious danger that it might become too remote from decision makers in the public sector and that its research priorities might not coincide with theirs. This could substantially reduce its impact on public policy and even endanger its viability.

The institute must identify its mission and its customer. In our view its mission ought to be to improve the social innovation process through its scientific activities. The public is of course the ultimate beneficiary of social innovation and in a democracy it can influence the process by expressing its preferences and priorities. But the innovations must be introduced or supported by governments.

That is why we believe the institute's immediate customer should be governments rather than the public. It should be completely free to publish its reports and to choose its research methods and its staff, but to fulfill its mission efficiently and to make a significant impact on the social innovation process it should operate within the framework of a strong customer-contractor relationship.

In this case we feel the customer should be the proposed Federal Provincial Ministerial Committee on Science and Technology. A research institute, as Lord Rothschild asserted, "cannot be so well qualified to decide what the needs of the nation are, and their priorities, as those responsible for ensuring that those needs are met."[7] He went on to describe the responsibilities of the customer:

> (a) He should decide, with advice or on his own initiative, that an R&D program is needed to achieve a specific objective. . . .
>
> (b) He should decide how much can be spent on the program. . . .
>
> (c) He should approve capital expenditure for the development, as opposed to the research, phase of the program and for new research buildings. . . .
>
> (d) He should determine priorities between programs.[8]

In exercising these responsibilities the ministerial committee should always seek advice and proposals from the institute. This would guarantee a meaningful government involvement. It would undoubtedly reduce the institute's freedom to determine its own programs but would directly link it with the decision making process and also relate its activities to real national needs. In our view this would far outweigh the advantage of complete independence. To compensate for the loss of freedom we suggest the institute should have at its disposal an additional sum of 20 per cent of the cost programs sanctioned by the customer for activities of its own.

Some of the major programs Ritchie mentioned as areas on which the institute should concentrate initially have a high priority. R&D programs on educational and health care systems should be added to the list. However, the Committee strongly suggests that the institute stay away from issues that are mainly economic in character, such as "the determinants of productivity and growth." It would merely duplicate missions already assigned to the Economic Council of Canada and similar provincial institutions. In the Committee's view it will have plenty to do if it restricts its R&D activities to social problems.

Ritchie rejects the idea that the institute might have two or more branches. He suggests that "it would seem preferable for the Institute to meet the need for regional links and knowledge by other means, including staffing policies, local consultation, local advisory groups, conferences and seminars, and the awarding of research fellowships to be held at the Institute."[9] While all these means may serve a useful purpose, we believe the institute will not be able to fulfill its important provincial missions without eventually having branches in the main regions. We can understand Ritchie's concern for efficiency and the need for a multidisciplinary effort within the constraints of a budget. But different R&D programs demand different skills. For instance, research and development on educational and health care systems will not have the same personnel requirements as the development of a set of social indicators. As the institute launches specific programs, its activities will lend themselves sooner than expected to a geographical division of labour. Personnel mobility can be achieved by reassigning permanent staff as specific tasks are accomplished.

From the outset the institute should set up a network of liaison and co-operation with researchers in provincial administrations, universities, and industry. As the activities of the institute develop, regional branches should be established as soon as there is justification for them.

The main message the Committee wishes to leave has two parts. One, Canada needs a national research institute on social policy to improve the overall R&D effort leading to social innovations and to avoid undesirable duplication at the federal-provincial and interprovincial levels. Two, for

the institute to succeed the provinces and the federal government must be directly involved in making the decisions on its financing and research priorities. Such an arrangement would bring the institute much closer to the innovation process and avoid the fatal danger of isolation.

The Committee therefore recommends that the name of the Institute for Research on Public Policy be changed to the Institute for Research on Social Policy and that the Federal-Provincial Ministerial Committee on Science and Technology proposed earlier approve its financing and its research priorities, provided that not more than twenty per cent of its budget be devoted to activities of its own choosing.

We hope the two levels of government will do their utmost to see that science policy matters become neither a battlefield nor an area where they ignore each other and pursue independent policies. Our country cannot afford the waste, duplication, and gaps that either of these courses would entail. There is room here for a sound division of labour; we offer three criteria:

1. The training programs for teachers, including related doctoral scholarship schemes, and research done in universities and similar institutions on the existing stock of knowledge should be the primary responsibility of the provinces, in collaboration with teaching and training institutions. As we pointed out in Volume 2 and as the Bonneau-Corry Commission has indicated, this role is important and has been neglected in the past.
2. Basic research aimed at extending the international pool of knowledge and applied research and development designed to lead to economic innovations should be the primary responsibility of the Canadian government. This would not mean, of course, that the provinces should be excluded from these two sectors. On the contrary, they should carry out scientific activities in these two areas to meet needs that are not satisfied by federal policies. Moreover, the Canadian government should consult the provinces as federal policies are formulated and implemented. This is the reason for the Federal-Provincial Ministerial Committee on Science and Technology.
3. Applied research and development aimed at social innovations and designed to improve our social systems should be conceived primarily as a joint responsibility of the two spheres of government. They should jointly sponsor the Institute for Research on Social Policy and assign a supervisory role to the new federal-provincial ministerial committee. The provinces and the Canadian government would remain free to initiate their own R&D programs

in this area to meet special needs not covered by the activities of the institute.

The Committee attaches great importance to meaningful consultation and active co-operation between the Canadian government and the provinces in the area of science policy. The financial and manpower resources Canada can devote to science and technology as sources of economic and social innovations are necessarily limited compared with those of many other nations, and as a country it is in our long-term interest to use them effectively rather than waste them.

THE CANADIAN GOVERNMENT AND INTERNATIONAL RELATIONS

The Committee has said repeatedly that the Canadian R&D effort, in terms of expenditures and manpower, could hardly exceed 2 per cent of the world's total. The obvious implication is that if Canada wants to improve its innovative performance substantially, Canadians will have to depend heavily on the results of foreign R&D and will have to learn to transform other countries' inventions into innovations and also adopt or adapt their innovations quickly. Otherwise they will suffer from a growing technological gap.

This dependence will demand a good network of international relations in the area of innovation, technology, and science. The Committee has found, however, that the government has not given the development of these relations the priority they should have in terms of allocation of resources and has not established the strategy for an effective information network.

Neither a narrow nationalism nor the self-serving chauvinism of special interest groups will be of much service here. The whole history of innovations illustrates the need to develop an openness to ideas developed elsewhere and to maintain close links with people outside. Even the superpowers are not independent of the R&D efforts of other countries—or their trained scientists and engineers. Canada, which in the past has required a great influx of qualified scientists and engineers, should be well aware of its beneficial and necessary interdependence with other countries.

1. *International organizations*

Canadians have taken an active part in the operations of international organizations interested in science and technology. The government

should also be prepared to make its full contribution, as it did at the Stockholm Conference on the Environment, when international institutions attempt to develop a collective solution to problems involving science and technology and transcending national boundaries. On the whole, however, it would be unrealistic to expect international organizations to fill the gap created by Canada's great dependence on the rest of the world in science, technology, and innovation. Direct relations with highly innovative nations are of paramount importance.

The Committee is also concerned by the natural inclination of specialized international institutions to build their empires in isolation and thus often duplicate the effort of others. The study of international problems involving science and technology has become fashionable and several international agencies seem tempted to join the bandwagon. International environment issues are a good example. The OECD, through its Directorate for Scientific Affairs, has been involved in science policy studies for many years and has issued many reports on this subject, including reviews of its members' national policies. More recently UNESCO has followed this example. For instance in 1970, as part of its Science Policy Studies and Documents series, it issued a report entitled *National Science Policies in Europe*. We doubt if such duplication serves a useful purpose.

Eugene B. Skolnikoff recently made a detailed examination of international organizations for his study, *The International Imperatives of Technology*, and reviewed some of the problems of these institutions:

> . . . it is clear that much time and energy is expended in internecine warfare that could more profitably be devoted to productive pursuits. It is unfair to single out one organization as a prime culprit in jurisdictional disputes, but in interviews throughout the U.N. system and with governments, UNESCO is usually cited as the organization that is most aggressive about enlarging its area of responsibility. If this is true, there are undoubtedly many reasons—one of the simplest being that UNESCO's areas of interest are not as well-defined as others are, since the "science" in the title can be interpreted to include all of the subjects with which we have been concerned. This lack of a clear focus gives free rein to empire-building tendencies within the secretariat, resulting in the aggressive tendencies noted by so many.[10]

Experience shows that agencies, especially those operating under the auspices of the United Nations, often move to more fashionable areas when their initial mission has been partly met. This is the law of survival. The temptation is great to brandish new activities related to problems that happen to be attracting the greatest popular attention at the time. This is why several agencies may move together but without consultation into the same program range.

Such trends should be checked. The Canadian government, through the Department of External Affairs and the Ministry of State for Science and

Technology, is reviewing this situation. It should be possible to stop creeping duplication before it is too late. Canada, as a medium-size power interested in fighting waste, is in an excellent position to take the initiative and make representations to the international agencies concerned.

2. *Government relations with other countries*

Traditionally, bilateral relations between countries have centred on political, defence, and economic problems. After the end of World War II science affairs began to be included. Then the emphasis shifted to include technology, and now there is greater concentration on innovation and technology. Eugene Skolnikoff has noted these trends and doubts that individual nations will adapt to them:

> The basic proposition I want to test is that likely developments related to technology in the relatively near future are going to generate important new demands on the international system and create new constraints on the independence of national action, to a degree little appreciated at present. If that is so (and the analysis strongly supports that proposition), it is essential to explore the character of these demands, and the capabilities of the existing system to respond to them. In oversimplified form, my general conclusion is that the system can *in principle* respond without fundamental change, given our ten- to twenty-year timeframe, but that the evolution that is required in system components and in governmental attitudes is substantial—so substantial, in fact, that there is real doubt that the necessary evolution in national policies and institution-building will take place.[11]

Skolnikoff points out that governments must try to relate their international science policy to their domestic scientific activities:

> What governments really must face is that their international science policy, their participation in international science programs and activities, is not an item separable from their national science policies or from their international political objectives. The desire to package all international programs together and separate them from domestic scientific activities in the planning or budgetary process can lead to misleading conclusions and poor planning criteria.[12]

Viewed in that perspective, the main goal for Canadian international involvement in science policy affairs has two parts. It consists first of obtaining information whenever foreign governments change their national science policy. This field is changing rapidly and it is important to know any new measures taken by other governments to improve their domestic R&D effort and the flow of innovations. This responsibility of our scientific representatives abroad can be easily accomplished since information on these matters is made public and therefore is readily

available. The Minister of State for Science and Technology, with its new terms of reference, should review these changes on a more systematic and continuing basis to determine if they should be adopted by the Canadian government. The Committee can speak with some experience here because it knows just how helpful detailed discussion with science policy experts, government officials, and others in eight industrialized Western nations was to its work on Canadian science policy.

Secondly, in order to support and complement Canada's R&D effort, it is important to gather as much information as possible on the R&D effort of other countries and their inventions and innovations. This task, which should also be assigned to our scientific representatives abroad, is more difficult but more important. The emphasis here should be put on technology rather than science, on inventions and innovations rather than scientific discoveries. The reason is obvious: most of the results of basic research are published in journals that are readily available, and good Canadian scientists are in touch with international science through "invisible colleges." The results of the last stages of the innovation process are not so easily accessible, however, and direct personal contact is often essential to secure information about them.

Bilateral agreements can be of some help. In negotiating such arrangements, the government should always insist that consultations and exchanges of technological information are beneficial to Canada. But the benefits to be derived from these intergovernmental agreements are limited especially where private enterprise predominates. The main advantage of bilateral agreements is to facilitate direct contacts with individuals and organizations as a channel for the transfer of technical knowledge.

Our scientific representatives abroad should play a key role in developing an effective network of personal contacts. They should keep up continual liaison with the most qualified representatives of the scientific and specially the engineering communities as well as with anyone who contributes significantly to science policy. They should monitor the local scientific, technological, and engineering press as well as the daily papers. They should also maintain liaison with representatives of the most important innovative industries. This is not an easy task but it is a crucial one given Canada's great dependence on foreign technological developments to sustain its innovative performance.

Our scientific representatives should become important sources for the Canadian technological information service. General organizational experience and results from psychological laboratories show that success in carrying out such a difficult assignment vitally depends on feedback and support from the home office. (This is what the psychologists studying vigilance and attention call "knowledge of results" or KR). If the response is silence, it is obvious that the representatives' motivation

will disappear. They must be told whether or not the information they supply is useful, who used it and in what way, and what additional data are required. They should have direct contact with those who need the information.

Technological information is a two-way street and our scientific representatives cannot become effective unless they are enabled to maintain a dialogue with people in the country in which they are posted. They cannot be continually asking for information. The home office must supply them with up-to-date, pertinent, properly packaged information about developments in Canadian innovation, technology, and science. It is also obvious that they should be selected on the basis of their background and skills so as to be able to carry on dialogues that will be beneficial to Canada and to their contacts overseas.

We offer a series of suggestions on how the Canadian government should organize its relations with other countries in the area of innovation, technology, and science:

1. It should be prepared to devote more funds and personnel to developing an effective technological information-gathering service abroad. The service would undoubtedly prove to be a sound investment. It will always be cheaper and less risky to get the results of other countries' R&D than to launch and support R&D programs of our own; the cost of not knowing what is going on is high. This suggestion may appear to reflect a self-serving attitude. We must remember, however, that Canadians are engaged in an international technological race and that they cannot remain in the race exclusively on their own strength. We must also be conscious of the fact that most other developed countries are playing the same game. Japanese practice is not unique, only the best illustration of what is happening throughout the industrialized world.
2. Canada now has scientific representatives in Washington, London, Paris, Bonn, and Brussels. Its representation should be extended to all countries that have demonstrated a high innovative performance and to the European Economic Community. Japan, Holland, Sweden, and Switzerland should be the next countries on our priority list. Moreover, in a country as large as the United States, Canadian representation should not be restricted to Washington; it should be extended to other main innovative centres such as Boston and the West Coast.
3. The organization of Canadian representation and the selection of its personnel should reflect our goals and their high priority. Our services should be integrated. This means that individual departments and agencies such as the National Research Council, the Defence Research Board, and the Department of Energy, Mines

and Resources should not have their own offices and representatives abroad unless they are part of the scientific missions within our embassies. If we want to avoid duplication, there should be only one line of communication from abroad.

4. The Committee agrees that the Ministry of State for Science and Technology should have a determining influence in the selection of personnel for our scientific missions. While the staff should continue to belong to the Department of External Affairs and keep it informed of their activities, administrative arrangements should allow for effective two-way communications between MOSST and Canadian scientific missions abroad. This would prevent undesirable delays in the transfer of information and ensure that our missions really serve the needs of the ministry.

5. The personnel of these missions should be recruited mainly from engineering fields rather than scientific disciplines, since the main purpose is to obtain technological not scientific information. In Sweden, for instance, scientific attachés are nominated by the Royal Swedish Academy of Engineering Sciences. Heads of scientific missions should be generalists rather than specialists, and have a wide knowledge of the technological needs of Canadian industry and expertise and experience relevant to their country of posting. A food technologist would be more useful in New Delhi than a particle physicist. If they prove to be effective, they should remain in the same post for a minimum of six years. They should have the rank of minister, instead of counsellor, in order to attract good people and give them the prestige they need to accomplish their difficult task and establish contacts at a high level.

6. In most countries, there is little value to having only one scientific representative. In order to play a meaningful role, heads of scientific missions must be assisted by adequate staff. Otherwise, they will only be able to do a superficial job and concentrate on routine assignments. In other words, the Canadian government must operate its missions at the proper scale if Canada is to derive the substantial benefits that an effective technological information service can produce.

7. The creation of this overseas service is just one part of an overall operation. It would be futile to gather interesting information on technological developments abroad if it were not processed and transferred quickly to potential users at home. In Volume 2 the Committee recommended the creation of new scientific and technical information and transfer systems. We hope this recommendation will be implemented soon, for without it even the small

amount of information gathered by our present scientific missions abroad remains largely unknown in Canada.

8. As these systems are further developed at home and as Canadian information services are improved abroad, the role of the international branch of the Ministry of State for Science and Technology should be carefully re-examined. Its main functions should be to process information on science policy changes in other countries so that MOSST will be constantly aware of such developments and in a better position to play its policy formulation role; to act as an intermediary between government scientific missions abroad and domestic scientific and technical information and transfer systems; to co-ordinate Canadian representation at meetings of international public organizations; and to encourage and support international relations at the private level. In other words, the main roles of the international branch should be played at home rather than abroad. Whenever possible, participation in meetings in other countries or at the international level should be left to heads of scientific missions, who would benefit from these opportunities to extend their own information network.

We expect the Department of External Affairs and the Ministry of State for Science and Technology will give some priority to reviewing their responsibilities and resolving whatever conflicts arise from their respective mandates in this area so that Canada may derive maximum benefits from the innovative and technological activities of the industrialized world.

3. *Encouragement of private international relations*

Canada's international relations should not be restricted to the government sector. The scientific and engineering community cannot flourish in isolation or merely by communicating through published material. Personal contacts, meetings of international private organizations and between private Canadian and foreign groups are all desirable, a necessary complement to the government information network.

It has been pointed out that Canadians are tempted to speak and publish abroad in order to establish an international reputation. A study of the *Year Book* of the International Council of Scientific Unions shows that, in proportion to population, Canadians are the most active of any people in international scientific bodies. (This inclination may have helped to reduce debate on domestic issues and make the Canadian scene duller.)

But private international relations cannot be left exclusively to the initiative of individual scientists and engineers. Scientific and engineering bodies must also be involved, not only for liaison with similar institutions in other countries but also to make Canadian participation in international private organizations more effective. In the past, Canadian private bodies were not active abroad; after World War II the National Research Council began to fill the gap, assuming many of the functions performed in other countries by private academies—another illustration of the uniqueness of the Canadian model.

The time has come for the Canadian government to provide more generous financial assistance to the private sector to help it assume its proper role in international relations. This should mainly mean a transfer of funds from public to private bodies. Obviously not all Canadian scientific and engineering societies can expect public support, for their sheer number would inevitably cause waste and confusion and create an unnecessarily complicated problem for the government.

In most countries, this role has been assigned to national academies, such as the Royal Society of London and the National Academy of Sciences in the United States. The Committee believes the same pattern should be followed in Canada and that this function should be given to the Royal Society of Canada. Although its membership is determined by peers, the society with its 700 fellows has a membership widely spread through the Canadian scientific community and embraces the natural sciences as well as the humanities and social sciences. In recent years, it has experienced a revival and is developing an interest in a new range of activities. The society has also begun to put more emphasis on its international relations. The president and honorary secretary have made a number of visits to sister institutions in many countries throughout the world; this activity is a continuing one.[13]

The society should make a study of the procedures followed by other academies, such as the Royal Society of London. It should define its program of activities, including the expenditures involved, and ask the Ministry of State for Science and Technology for a grant to meet these additional expenses. The society should exercise its new function in close collaboration with the ministry's international branch and with other Canadian private scientific and engineering bodies. An implication of this proposal is that public bodies such as NRC would phase out their activities in this area.

The Committee therefore recommends that the Royal Society of Canada, with the assistance of a special grant from the Ministry of State for Science and Technology, assume the overall responsibility for developing and maintaining relations with foreign private scientific and engineering bodies,

in close co-operation with the International Branch of the Ministry and the specialized scientific and engineering associations existing in Canada.

The Committee would like to see this system operate until 1980 on an experimental basis. During that period, the Ministry of State for Science and Technology should carefully monitor its effectiveness. This proviso is based on the historical fact that organizations and situations can change. For example, the Royal Society of London began with a considerable emphasis on practical problems but eventually developed a distaste for them. However, according to an OECD report, "the Society has recently shown a particular interest in the status of technology in the United Kingdom and has decided to reflect this interest in new appointments to membership."[14]

The new responsibility of the Royal Society of Canada should not, of course, prevent other societies from establishing their own relations with private bodies abroad. There has to be a practical division of labour in such matters. The Committee expects, therefore, that in pursuing its international responsibility the Royal Society of Canada would work closely with other societies in Canada and with SCITEC.

Technical missions, organized on an industry basis, have been sent recently to Germany, Japan and Belgium. Empirical studies show that the best channels, specially for the transfer of technical ideas, are personal contacts. The government should further encourage and sponsor such visits on a more systematic basis and the international branch of MOSST should play a key role in this area. Missions might arise out of suggestions from our scientific representatives abroad who have detected new technical opportunities that could interest specific Canadian industries. Or they could come from an industry's desire to establish direct contacts with technical people working in the same field in another country. Such technical missions could help Canadian industries quickly adopt or adapt new technology developed abroad. Planned well, such visits should cost little in relation to the possible benefits.

The Committee believes the innovation potential of Canadian firms would be greatly enhanced if they were to develop partnerships with related independent companies in other countries. Some people have even suggested that such arrangements will become an effective response to the threat of large multinational corporations. Canadian manufacturing companies face the same problems of developing a world market for their products experienced by independent firms in other countries and are exposed to the same dangers of take-over or extinction. They can respond by jointly developing or marketing complementary lines of products. The European Economic Community has organized a "marriage bureau" in Brussels to bring together smaller firms so that they can expand by becoming more interdependent.

The Committee has not studied these problems in any depth, but we believe that various forms of partnership linking complementary companies in different countries might help smaller firms to survive in the future.

The Committee therefore recommends that the Ministry of State for Science and Technology and the Department of Industry, Trade and Commerce develop a "marriage bureau" for those firms in Canada which are free to develop new products and services for the international market and that they develop mechanisms and services for expediting partnerships between these Canadian firms and complementary companies in other countries, including the sponsoring of industrial visits abroad.

In Volume 2 the Committee made a set of recommendations designed to improve Canada's R&D effort. We are convinced, however, that even if the proposed targets, strategies, and administrative reorganizations are adopted, our country will remain heavily dependent on foreign R&D and inventions as it attempts to improve its innovative performance. We regret that Canada has neglected technological knowledge available in other countries to such an extent that we have exported ideas and imported manufactured goods, instead of importing ideas and exporting products.

These trends must be changed. We have to extend and improve our network of scientific and technological information at home and abroad and make sure it is well adapted to the needs of Canadian industry. Canadian companies with the ability and freedom to expand internationally must be encouraged to associate with complementary firms in other countries. Additional investments by the Canadian government to attain these objectives could produce substantial benefits.

THE CANADIAN GOVERNMENT AND PARLIAMENT

In the past Parliament has discussed a few specific science policy issues, like the development of the Canadian nuclear program, but these reviews have been sporadic and superficial. It has been difficult to generate systematic discussions on general science policy matters. This is not surprising, since annual estimates of expenditures have not been presented so that the government's scientific programs were visible. Moreover, to most parliamentarians science policy appeared to be an esoteric subject remote from the immediate problems of real life, mainly involving questions of basic research best left to scientists. Like motherhood, science was seen as a good thing to be supported without too much questioning.

Recently, however, the situation has begun to change as it has gradually been realized that science and especially technology could significantly affect the growth of the economy and the quality of life. Parliamentary or congressional committees on science policy matters are increasingly active in the United States, the United Kingdom, and France. In Canada, the Senate Committee on Science Policy is an expression of parliamentarians' new interest in this area.

The creation of the Ministry of State for Science and Technology has made science policy more visible to Parliament. We hope that our earlier proposal of a separate science budget will be accepted by the government. This would require proposed scientific expenditures to be shown separately for each department and agency in the *Main Estimates*, tabled each year by the President of Treasury Board. The Minister of State for Science and Technology would also have to table a document containing the science budget or the consolidation of the estimates covering scientific activities by department and agency. This double-barreled procedure would allow Parliament to review the science budget both microscopically and macroscopically. Microscopically, the parliamentarians would evaluate the scientific activities of each department and agency in the light of its policy and operational mission. Macroscopically they would concentrate on the size and distribution of the overall science budget in order to detect gaps, duplication, and undesirable trends in balance.

With this system, we believe a proper division of labour could be arranged between the House of Commons and the Senate. The procedure we have in mind would not require the science budget as a whole to be approved separately. The House of Commons could take the responsibility for the microscopic review, and so would not have to change its approach to the consideration and approval of estimates. The specific science budgets of departments and agencies would be considered with their other estimates by the appropriate committees of the House, as they are now. But separate presentation of these specific science budgets could be expected to make them more visible and would therefore allow the committees to devote more attention to them than they do at present. Arrangements could easily be made for a general debate on the science budget as a whole afterwards if the House wished. An annual debate might be extremely worthwhile.

The Senate, through an appropriate standing committee, could assume responsibility for the macroscopic view and consider the science budget as a whole to detect undesirable trends. Senate committees, which have a slower turnover in membership, are in a particularly good position to develop special expertise and look beyond annual estimates. They have more time than committees of the House to devote to particular subjects. They do not have to allocate time limits for questioning to each political

party. Their consideration of complex matters, such as general science policy issues, can be more flexible and extensive.

Of course, the Senate standing committee would have no authority to change the science budget or even formally approve it. However, at the end of its annual review, its report would be tabled in the Senate and become part of the public record. It could be discussed in the Senate, constitute a useful background for the annual debate in the House on the overall science budget, and provide another source of advice for government action designed to improve science policy. It would also keep interested Canadians better informed on the orientation and content of science policy.

The Committee therefore recommends that an appropriate standing committee of the Senate be authorized to review the annual overall science budget proposed by the government, to hold hearings for this purpose, and to prepare a report containing its comments, suggestions, and recommendations.

If Canadian parliamentarians are to develop a greater expertise in science policy matters, they must extend their activities beyond Parliament and establish relations with the Canadian scientific and engineering community. Sweden has shown a good way to formalize relations between parliamentarians and those involved with innovation, technology, and science. The Royal Swedish Academy of Engineering Sciences began to arrange lectures, demonstrations, and study visits for Swedish MPs in the 1950s, and in 1959 the association linking parliamentarians with engineers and scientists was founded (the Swedish acronym for this organization is RIFO).

RIFO's activities centre on study visits and the discussion of specific subjects, such as the role of research in the supply of power, radioactive fallout from Soviet nuclear tests over the Arctic, technical aid to underdeveloped countries, environmental preservation, the problems of urbanization, medical technology and medicine, space and noise research, bacteriological warfare, and the role of Swedish science policy advisory organizations. Each year RIFO has arranged a study trip to industries and institutions in a different part of Sweden.

The association has also held meetings with groups of European parliamentarians interested in science policy. It celebrated its tenth anniversary by meeting the Committee on Science and Technology of the Council of Europe.

About two thirds of Sweden's 250-or-so parliamentarians are members of RIFO and there are about 200 representatives from the scientific and engineering community. The statutes prescribe that members shall be elected by the board, though in practice this applies only to scientists and

engineers. The board consists of four MPs, four scientific and engineering representatives, a secretary, and a treasurer. It is claimed that the activities of the organization have greatly improved parliamentary debates on science policy matters.[15]

The Committee was approached some time ago by scientists who wished to establish similar relations with Canadian parliamentarians. At that time the idea appeared premature to us. A new situation will arise, however, if the suggestions made previously are implemented and if, as a result, parliamentarians become more involved in considering science policy and examining government scientific activities. Meetings and exchanges of views between parliamentarians and scientists and engineers could then be very useful. Some scientists have asserted that parliamentarians do not know how science works. Our hearings and subsequent discussions have also shown that some scientists do not know how Parliament works. There is an obvious need here for dialogue between the two groups. The first step should be to set up a joint committee of parliamentarians which would then be authorized to meet representatives of Canadian scientific and engineering bodies, including the Royal Society of Canada and SCITEC, to discuss the creation of a new association.

The Committee therefore recommends that a group of parliamentarians from the Senate and the House of Commons be organized to study science policy matters and problems and opportunities raised by science and technology and that, in order to attain this objective, it be authorized to form in due course a Canadian Association of Parliamentarians, Scientists, and Engineers (CAPSE) in collaboration with representatives of scientific and engineering bodies.

The association's membership should be limited to keep it manageable. It could meet periodically when Parliament is in session and meetings should be organized to permit free and informal discussion on a specific topic under review. The Committee would like to stress the desirability of including among the scientists and engineers some who have been associated with successful innovations in the international market. The Committee also believes that the concept of study visits developed by RIFO in Sweden is even more suited to Canadian conditions and suggests that each year a CAPSE group study the institutions involved in science, technology, and innovation in a particular region of Canada.

It was in Volume 1 that the Committee first declared that the politician and the scientist must become partners:

> They must not only live together but work together and help each other to serve society better. It can be a most rewarding challenge for the scientist with his new responsibilities to integrate himself into society. The researcher will of course

> have to remain a true scientist but he will also become a servant of the public with important social functions to fulfill. The politician will have to remain the guardian of the public interest but he will also become more aware that scientific progress needs a climate of freedom. This is the kind of mutual respect and comprehension that must develop between the politician and the scientist, if the goals of society and science are to be met.[16]

The Committee also believes that a partnership must be formed between the politician and the technologist and the successful innovator, and hopes the proposed association will help to develop this new partnership.

Canadian parliamentarians must also have the opportunity to discuss science policy issues with their colleagues in other countries if they are to improve their expertise in this area. We noted that the need for an exchange of views was also felt by parliamentarians in other countries when we visited Washington and several European capitals. They were concerned that they were not getting enough information from their governments and lacked the expertise in science policy issues to fulfill their role properly.

The Committee has come to the conclusion that an interparliamentary association would meet this need. At present, the OECD organizes annual ministerial meetings in Paris but the discussions do not help *parliamentarians* to play their roles as legislators. As Canada is preparing to revise its targets, strategies, and government organization for science policy, the Canadian Parliament would be in a good position to take the initiative and propose the creation of a new association.

The Committee therefore recommends that the group of Canadian parliamentarians proposed above be authorized to invite parliamentary delegations from OECD countries to a conference in Ottawa for the purpose of creating an Inter-parliamentary Association on Scientific Affairs.

(The proposed organization would be restricted to parliamentarians, but the Committee can foresee that the Canadian Association of Parliamentarians, Scientists and Engineers [CAPSE] might also wish to hold meetings with similar bodies in other countries.)

We have good reason to believe that parliamentarians in many countries would welcome such an association. The group could hold annual meetings in different capitals which would provide the additional opportunity for parliamentarians to learn on the spot how other countries are developing their national science policies. The experience of the Committee during its visits abroad demonstrated that published material on science policy issues is not an adequate substitute for personal contacts. Government officials and experts from other sectors are understandably inclined to be more straightforward and provide more information at in-camera meetings than when they write for a public journal or speak on a public platform.

THE GOVERNMENT AND THE SCIENTIFIC AND ENGINEERING COMMUNITY

When the Committee held its hearings, it found the scientific and engineering community deeply divided and ill equipped to add significantly to the discussion of science policy matters. There were over a hundred learned societies and professional associations existing more or less in isolation. The Social Science Research Council and the Humanities Research Council had just been revived. The Royal Society was restricting its activities to its annual meetings and some symposia. The briefs presented to the Committee seldom dealt with the broad issues of science policy and when they did they largely reflected myths about the innovation process.

Members of the Committee expressed their concern about this diffusion and the inability of the science and engineering communities to add much to the development of a better science policy. We suggested to some professional associations that the scientific community should use a broadly representative national body as a main channel. They agreed with the suggestion but rejected the idea that the Royal Society should play this role. As a result, SCITEC was born in 1970.

Since then, it is our impression that the new body has not had an easy life. Lack of funds proved to be a significant impediment, but it was not the only one. Natural scientists, social scientists, and engineers found it difficult to speak the same language and agree on a set of conclusions. The split appeared to be more serious between the natural sciences and the social sciences. The Committee has also been puzzled by discrepancies in the response to the SCITEC questionnaire based on the 45 recommendations of our Volume 2 and the reaction of workshops at the SCITEC forum in Ottawa on the same subject.

In private discussions members of the Committee have gathered that scientists and engineers outside the government establishment have been kept happy by the generous grants they receive but have been more effectively strait-jacketed than in most other countries. It is said that their allegiance is divided because many have served on the National Research Council and similar bodies, that they have little opportunity to draw attention to unpalatable facts, and that they could hardly expect to be appointed as members of councils and committees if they were suspected of voicing opinions radically different from those held by the heads of those bodies. It is further contended that the government has monopolized the publication of scientific papers in Canada by subsidizing Canadian journals of research and that these journals effectively stifle discussion by refusing to provide a section for letters to the editor or to publish the proceedings of most symposia.[17]

The situation may not be as bleak as it has been depicted. But the great influence that the government scientific establishment has on the rest of the scientific and engineering community cannot be denied and should be corrected. It is not to the government's advantage to rely exclusively on its own establishment for its scientific information and advice while the rest of the community remains passive, disorganized, and subdued.

This private community can never become completely homogeneous or completely independent. It is too diversified in terms of disciplines and sectors of performance to be perfectly integrated and to develop a high common denominator. It would be impractical and undesirable to exclude members of the government establishment from its representative bodies, and, as experience has shown, both here and abroad, these associations cannot operate properly without the financial support of the government.

However, even under these conditions, similar institutions in other countries have managed to play useful and dynamic roles and to maintain a high degree of independence. In the last analysis, the vitality of these associations depends to a large extent on the intellectual integrity and quality of their members. Recently there have been signs of a revival in Canada. Prof. Allen S. West has underlined this new interest in science policy in his recent study of national engineering, scientific, and technological societies:

> Several organizations have for some years had what could be termed science policy committees, but this has been the exception rather than the rule. In conjunction with the preparation of briefs for the Lamontagne Committee, starting in 1968, and with the preparation of responses to the Committee's reports, the establishment of a science policy committee has become a regular feature of the organization of societies. At least 25 societies have such a committee, and at least another 40 "speak" through the science policy committee of a liaison body. As might be expected, Annual Reports reveal that the degree of activity of these committees is extremely variable. Some committees are apparently concerned only with the Lamontagne Reports; encouragingly, others are making the issue of science policy a major involvement.[18]

The Royal Society of Canada has intensified some of its traditional activities, undertaken new initiatives, and increased the number of its symposia.[19] The exchange of formal visits with other national academies has been revived. It has established committees to advise the Department of Communications and maintain liaison with the Ministry of State for Science and Technology. It is actively investigating how it might help the International Development Research Centre. In expanding its activities, it must respond positively to Professor West's criticism that "the Royal Society does not have the confidence of the scientific community, which is not to impugn the reputations of members of the Society,"[20] and it must guard against the temptation of becoming a blocking institution to protect its fellows. It must also guard against conflict of interest in situations

where its committees are advising departments and agencies whose senior scientists are fellows intimately concerned with the management of the society's affairs.

The Association of the Scientific, Engineering and Technological Community of Canada (SCITEC), in spite of its recent creation, has already held several meetings. Even more promising for the future is the observation of its president, Dr. Virginia I. Douglas, in an article in *Science Forum*:

> Certainly the scientific, engineering and technological associations have been challenged to re-examine their own goals and to give serious thought to their responsibility for helping define a science policy for Canada. Perhaps sufficient momentum has been established to enable us to accept some responsibility for leadership rather than remaining in the position of reacting to the initiative of others.[21]

The management committee of SCITEC, of which Dr. Douglas is a member, has published some pertinent remarks on this question in its report, "Perspectives and Recommendations":

> The lack of rapid and reliable communication with the scientific community has caused repeated embarrassment to government, and frustration to scientists and engineers. It is now generally accepted that such communication is necessary and should be organized on a continuing, formal basis if the nation is to benefit from the large bank of expertise represented by the totality of Canada's scientists and engineers.[22]

The lack of communication between groups in Canada is a problem whose cost—if it were known—would surely be staggering. For example, Dr. Roger Gaudry, chairman of the Science Council states that only in recent months have the faculties of forestry or the faculties of agriculture of Canadian universities held national meetings. Dr. Gaudry writes that these meetings, sponsored by the Science Council, were the first of their kind to be held in Canada:

> It is interesting to speculate why the Forestry Service in Environment Canada with a research budget of nearly $26 million or the Department of Agriculture with a research budget of nearly $53 million apparently accord lower priority to discussion of the state of Forestry or Agriculture in our universities than does the Science Council with a total budget of $1.4 million.[23]

SCITEC's management committee asks the question, "Are the societies now providing effective communication between government and the 'grass-roots' scientist?" and answers, "Clearly 'no!'" It points out that the individual society was never really intended to perform this role and suggests why SCITEC is so useful in fulfilling the function:

> The difficulty is that most of the science-based societies in Canada were formed to promote a single discipline while most of the problems to which Canada wants

> scientific solutions are interdisciplinary in nature. The expertise required to give the best possible advice rarely exists within a single scientific society. This implies that the societies must so organize themselves that the appropriate mix of expert advice can be marshalled quickly from several societies when the need arises. And the need may be expected to arise ever more frequently in the future.[24]

So Canada now has two broadly representative bodies that appear to be ready to play an active role in providing the government with information and advice on science policy matters and problems involving science and technology. Membership of the Royal Society is determined by peers on the basis of scholarship, but the composition of its technical panels is not restricted to its fellows. SCITEC is a loose federation of professional organizations but it accepts individual membership. Several specialized societies are going through a period of revival. Their more meaningful activities are encouraged by the National Research Council. For instance, NRC decided in 1972 to phase out its associate committee on geodesy and geophysics and its subcommittees. It is intended to transfer its functions to the Canadian Meteorological Society which would receive financial support from the council for meetings and publications.

While this revival is highly desirable, it might lead to a confusing proliferation if there is no serious attempt to co-ordinate and simplify the lines of communication. We believe that the Ministry of State for Science and Technology should have the main responsibility for defining and co-ordinating the government's relations with national private societies and for distributing supporting grants to these bodies. This responsibility is directly related to the national and international mission that MOSST should have. Thus, NRC and the Canada Council should phase out their activities in this area. This arrangement will be even more desirable if these agencies are assigned new missions in the light of the Committee's recommendations presented in Chapter 14 and reviewed in Chapter 21.

The ministry, on the other hand, cannot be expected to maintain direct and continuing contacts with the 119 Canadian societies which have been identified by Dr. A. S. West. This would be an impossible task. Some people are even worried that the Canadian government may develop a special and formal relationship with two broadly representative bodies, namely the Royal Society and SCITEC. This may raise difficulties if the two decide to ignore each other or compete for territory but it also offers opportunities for division of labour and co-operation. Countries like the United States and the United Kingdom have national academies and associations for the advancement of science.

It should be possible in Canada to divide the territory on the basis of these two different organizational concepts. The Royal Society, with its reservoir of scholarship represented by its fellows and scientific panels, could concentrate its national activities on the use of science for policy—

on scientific and technological studies dealing with Canadian issues. SCITEC, as an overall spokesman for the engineering, scientific, and technological societies, could specialize in policies for science and technology—on broad issues concerning scientists, engineers, and technologists in the exercise of their professions. Of course, SCITEC's activities would have to be restricted by the role delegated to it by its member organizations, which would continue to represent the views of their own constituencies.

In his annual report as president of the Royal Society, for the year 1972-1973, Dr. J. T. Wilson stated:

> As did the Past-President last year, the President attended the annual meeting of SCITEC, and pointed out that there should not be any conflict of interest between the Society and SCITEC, because in both Britain and the United States bodies analogous to SCITEC, the Associations for the Advancement of Science, have flourished side by side with the Royal Society of London and the National Academy [of Sciences] for over a century.[25]

The Committee strongly recommends that the executives of the two national bodies meet to define their roles and set up a liaison system to prevent overlapping in grey areas and identify opportunities for co-operation. They should settle these issues themselves and not expect the government to do it for them. The organization of the Canadian scientific and engineering community would be greatly strengthened by the co-existence of two broadly based private national societies capable of playing complementary roles as sources of information and advice to the government on science policy issues and on problems involving science and technology.

However, these bodies cannot be expected to render the public services they could and should without adequate financial support from the government. We know this from the experience of other countries. For instance, all national academies abroad receive *substantial* government assistance and are handsomely housed.

The government should try to strengthen its relations with SCITEC and the Royal Society. In this complex and controversial policy area, we believe private societies should have the oppportunity to make their own independent investigations and assessments. The new "make-or-buy" policy should apply to them as well.

Chapter 20 includes a number of suggestions to make the Science Council a more meaningful intermediary between the government and the scientific and engineering community. In addition the Committee believes the chairman and vice-chairman of the council should consult periodically with SCITEC and the Royal Society to get their views on the council's program of activities. Moreover, we suggest that most of the special studies the council sponsors should be assigned on a contractual

basis to these two national bodies, instead of being carried out by its staff and *ad hoc* committees. Contractual arrangements should cover direct as well as overhead costs.

This application of the contracting-out principle would present several advantages. It should give greater credibility and authority to the studies prepared for the council. It would strengthen the position of the two private bodies and enable them to play a larger and more useful role. It could improve the council's advisory function; the council could take a more detached view of studies made by a panel it had not selected and its recommendations might have more impact on senior decision-makers because they had been formulated after consultation with representative organizations of the community. And it would permit the council to carry its mission effectively with a very small staff and avoid the launching of studies merely for the purpose of keeping the personnel busy—the "publish or perish" problem.

The Ministry of State for Science and Technology should also consider the contracting-out principle for its own needs and those of other government departments and agencies for special studies on science policy issues.

We stress that in their new roles the Royal Society of Canada and SCITEC should not rely only on their membership. They should also call on outside experts at home and abroad whenever appropriate; Canada should use foreign know-how as much as possible in the national interest.

The Committee therefore recommends:

1. That the Ministry of State for Science and Technology be mainly responsible for defining and co-ordinating the Canadian government's relations with private scientific and engineering societies, that the present activities carried out by NRC, the Canada Council, and similar agencies in the area of relations with such private bodies at the national and international level be phased out and that the funds allocated by these government agencies for this purpose be transferred to MOSST;

2. That the Ministry formally recognize the Royal Society of Canada and the Association of the Scientific, Engineering and Technological Community of Canada (SCITEC) as the two main spokesmen of the Canadian scientific and engineering community in the areas of science for policy and policy for science respectively;

3. That the new "make-or-buy" policy be applied in these two areas by all government departments and agencies, especially by MOSST and the Science Council, and that studies they require on these two topics be contracted out whenever desirable to the Royal Society and SCITEC;

4. That the Ministry of State for Science and Technology make an adequate, annual, unconditional grant to these two national bodies—the

amount to be determined after consultation with them—for the purpose of enabling them to maintain an efficient secretariat, to undertake a few studies on their own initiative, to hold periodic symposia, and to finance their publications;

5. That these arrangements be for the 1970s and be evaluated for review in 1980.

The official status conferred on SCITEC and the Royal Society would impose certain obligations on them, and in the process provide indirect but real benefits to other more specialized professional organizations. For instance, the Royal Society might broaden its membership by establishing new sections for engineering and medicine and in these two cases at least determine new criteria for the selection of its fellows. It is time to realize that engineering is not only "applied science" and to recognize the medical arts. It should also restructure certain of its existing sections to provide more homogeneity. SCITEC should give adequate recognition to the social sciences and the humanities and provide for greater representation of these disciplines in its structural organization.

The time has come for strong and respected national private bodies to use the great capability of the scientific and engineering community to provide independent information and advice on science policy issues. They will not be able to do this effectively without financial support from the government; but in the last analysis, it is the government and the Canadian public that will be the beneficiaries of the services the private societies will be able to provide.

FRENCH SCIENTIFIC AND TECHNICAL TERMINOLOGY

The interfaces of science policy essentially involve problems of communication, understanding, and participation. Thus they raise a linguistic issue. Scholars of all countries feel the need to communicate in a common language. In the 18th century Latin was replaced by French and now English is prevalent. However, in a bilingual country like Canada this common language cannot be the only medium of scientific and technical communication. This would be contrary to the policy of the Canadian government, which was reaffirmed by Parliament in June 1973.

The state of scientific and technical terminology in the French language is far from being satisfactory today, and is worsening rapidly. In the light of our own experience since 1968 we can assert that this is as true in other countries as in Canada. At the biennial of the French language held in Liège in 1969, it was agreed that French scientific and technical terminology lagged about 5,000 words behind English ter-

minology, that is, 5,000 scientific and technical words in English have no French equivalent; and at the biennial of 1971 in Menton it was announced that the lag in French terminology is increasing at the rate of 1,500 expressions every year.

Two factors are mainly responsible for this growing gap. First, there is a lack of co-ordination of individual and collective efforts in the creation of an adequate French terminology. Secondly, the methods used to develop the terminology are archaic, costly, time-consuming, and confusing. Thousands of glossaries, manuals, and dictionaries take space in our libraries. Special publications are issued for different disciplines and often contain contradictory information. The use of these increasingly extensive reference sources wastes time and money and is becoming a nightmare for researchers, authors, and translators. (For instance, the translation service of the Science Council owns 1,500 glossaries, 300 handbooks, 100 dictionaries, and 40,000 terminological cards.)

The lack of terms and the frustration created by confusing reference material often lead authors to create their own terminology without consultation, which makes communication almost impossible. It has been estimated that terminological research for the translation of one page of scientific or technical texts takes an average of one hour (about fifteen minutes for every expression, and there are typically four unknown expressions requiring research to a page). What is worse, translators at work on English texts containing terms that do not exist in French are, like authors, tempted to invent expressions; this often makes the translation itself incomprehensible.

The situation must be corrected. A frontal attack must be mounted on the two main causes of this growing crisis. The lack of co-ordination must be replaced by standardization, and the updating of French scientific and technical terminology must be speeded up. This task requires the active participation of scientists, linguists, authors, translators, journalists, and all other users of French as a working language and it must be integrated by a central organization with an international character and reputation.

A provisional committee with wide representation from the scientific and technological communities and the academic, industrial, and government sectors was set up in Canada in 1972 to consider this acute problem. It has consulted a number of people concerned with this issue not only here but in other countries including France. The committee recently submitted a report to the Ministry of State for Science and Technology suggesting the creation in Canada of a *Service international de terminologie scientifique et technique* (SITEST).

The organization would have a status similar to that of the International Development Research Centre's. It would rely on the participation of the best scientific, technological, and linguistic manpower resources

available and work closely with similar institutions in interested countries. This Canadian initiative has already been welcomed internationally.

The Committee believes that it is a natural vocation for Canada to launch this new venture. With the growing use of French in our country, we have a greater need for the service than other nations. Indeed, we are often the first to be confronted with new English scientific and technical terminology because of our proximity to the United States, which contributes about half of the world's R&D effort.

SITEST would, in addition, abandon the archaic and wasteful methods presently employed. It would centralize the standardized terminology in the computer already operating at the University of Montreal under experienced technicians and linguists. The computer would store bilingual terminological information including full details on the term and its uses. The capacity of the computer is practically unlimited and allows for all kinds of classifications, such as alphabetical, analogical, and disciplinary. The new service would be economical and quick; it is estimated that the terminals, that is the equipment linking customers with the terminology reference centre, could be rented at $80 to $125 a month. The time devoted to terminological research would be reduced by a factor of five for a single reference.

The Committee therefore recommends that a *Service international de terminologie scientifique et technique* (SITEST) be established by the Canadian government with appropriate international representation and operated as a Crown corporation.

There are several reasons why the new service should be launched and operated by the Canadian government. SITEST, to be successful, will have to rely on active international participation. The proposed organization should be regarded as an important element of federal bilingualism policy. The government will be the largest Canadian customer of the service. During its first years of operation, SITEST will run a string of annual deficits. Although this situation will likely be temporary, we suggest the government treat these deficits as a sound investment, based on the expectation that the new organization will eventually become profitable.

CONCLUSION

The interfaces of science policy involve a wide range of important issues that have been seriously neglected up to now in Canada. They must be dealt with systematically and successfully if national science policy is to

make its full contribution to Canada's long-term quantitative and qualitative development. These interfaces have four main dimensions.

First, they cover federal-provincial relations. As provinces begin to devote more attention to science policy, the two main spheres of government must do all they can to avoid confrontation and to solve problems in a climate of mutual understanding and co-operation. A federal-provincial ministerial committee on science and technology should be created soon to divide responsibilities and maintain liaison between governments.

Secondly, international relations are also of crucial importance for Canada because, as a small country, we depend on the results of innovative activity, technological development, and scientific discovery abroad to sustain an adequate flow of domestic, economic, and social innovations and a high degree of scientific excellence. And yet the Canadian government has neglected these relations and has shown itself reluctant to make the investment required to get the maximum benefits from them. While Canadian participation in the activities of international public bodies involved in science and technology is useful, the emphasis should be put on relations with individual countries that sustain an effective national R&D effort and have a good innovative record. The government should have scientific missions in all such countries. The main role of these missions should be to gather information about technological developments. To do this they should be aware of the needs of Canadian industry and professions and of foreign inventions and innovations that can be exploited in Canada. They should be adequately staffed with people with the appropriate background and capable of establishing effective personal contacts at the appropriate levels.

The Canadian government should also encourage international relations at the private level. It should support the Royal Society of Canada in maintaining contact with similar bodies in other countries and with such private institutions as the International Council of Scientific Unions. The government should help private technical missions on an industry or professional basis. These visits should not only be well planned in advance at home but well organized abroad in close co-operation with our scientific representatives.

Thirdly, the interfaces of science policy also involve the relations between the Canadian government and Parliament. The government must support parliamentarians in the more active consideration of annual estimates devoted to R&D and other scientific activities and in discussing broad issues raised by science and technology that are vital to the future of our society. If the *main estimates* were to separate the proposed scientific expenditures of individual departments and agencies, appropriate committees of the House of Commons could devote more attention to them. Moreover, if the Minister of State for Science and Technology were to consolidate these items into an overall science budget, an

appropriate committee of the Senate could consider and assess it. These reviews of specific programs and the overall science budget by committees of the Senate and the House of Commons could lay the ground for general debates on science policy issues in Parliament.

To help Canadian parliamentarians play this role more effectively, a joint parliamentary group on innovation, technology, and science should be formed. It would be authorized to co-operate with the Royal Society and SCITEC in organizing a Canadian association of parliamentarians, scientists, and engineers which could meet periodically when Parliament is in session to discuss matters of common interest. In addition, the joint *parliamentary* group should be authorized to invite parliamentary delegations from OECD countries to a conference in Ottawa for the purpose of creating an inter-parliamentary association for science and technology which could meet once a year in different national capitals.

Fourthly, relations between the Canadian government and the private bodies broadly representative of the scientific and engineering community should be improved. The Royal Society and SCITEC should be given a special status as the two national organizations the government would use as its main channels of communication to the community at large. Unconditional grants should be given to these two bodies to permit them to increase their own independent activities, revitalize themselves, and establish better links with more specialized professional associations and with as many individual scientists and engineers as possible. In addition, government departments and agencies, including MOSST and the Science Council, should whenever desirable contract out the special studies they need to these two national bodies. Such an arrangement should be tried for the rest of the 1970s and if these private organizations successfully meet the challenge several advantages will result, including that of providing the government with information and advice from independent institutions to complement similar services within the public establishment.

To fulfill these important new tasks efficiently the Royal Society and SCITEC should carefully re-examine their internal structure, consult together closely, avoid an elitist approach, and improve the democratic character of their operation, so as to earn the recognition from professional associations and individual scientists and engineers that they are really reflecting the prevailing views of the scientific and engineering community. If this new challenge is offered to them and should they not respond to it efficiently and with creative imagination, they will have only themselves to blame when the government decides, on the basis of their inadequate response, to withdraw its support to them. The Committee hopes they will not fail in their new missions, because if they do, a regrettable gap will remain in the relations between the Canadian government and the scientific and engineering community.

NOTES AND REFERENCES

1. *Canada's Crisis in Higher Education,* Edited by Claude T. Bissell, University of Toronto Press 1957. p. 231.
2. *Targets and Strategies for the Seventies, op. cit.,* p. 608.
3. Patrick Moynihan recounts in *The Politics of the Guaranteed Annual Income* how people with a vested interest in the welfare system helped to block a move in the U.S.A. toward a guaranteed annual income. Moynihan suggests that people are remaining on welfare because of the threat welfare workers saw to their own livelihood.
4. Ronald S. Ritchie, *An Institute for Research on Public Policy,* A Study and Recommendations prepared for the Government of Canada, December, 1969, Information Canada 1971, CP32-13/1971.
5. Ibid., p. 53
6. Ibid., p. 54.
7. Rothschild, *op. cit.*, p. 4.
8. Ibid., pp. 4 and 5.
9. Ritchie, *op. cit.*, p. 56.
10. Eugene B. Skolnikoff. *The International Imperatives of Technology: Technological Development and The International Political System.* Research Series, No. 16, Institute of International Studies, University of California, Berkeley, 1972, p. 148.
11. Ibid., p. 5.
12. Eugene B. Skolnikoff, *Science, Technology, and American Foreign Policy,* The M.I.T. Press, Cambridge, 1967, p. 80.
13. J. Tuzo Wilson, "The scientific societies: what are they and what should they become," *Science Forum.* April 1973.
14. *United Kingdom and Germany,* Reviews of National Science Policy, OECD, Paris, 1967, p. 191.
15. Information brochure prepared by RIFO (Sallskapet Ricksdagsmän Och Forskare), 1969: 1022, BE/IK 50.
16. The Senate Special Committee on Science Policy. *A Critical Review: Past and Present,* Ottawa, 1970, p. 271.
17. For further comments along those lines see: J. Tuzo Wilson, *op. cit.*
18. Allen S. West, "Background Study for the Science Council of Canada", Special Study No. 25, *National Engineering, Scientific and Technological Societies of Canada,* December 1972, p. 46.
19. J. T. Wilson, Report of the President for the year 1972-1973, presented at the annual meeting of the Royal Society of Canada at Kingston in June 1973.
20. West, *op. cit.*, p. 104.
21. "The scientific societies look at science policy: a summary of their brief", *Science Forum,* February, 1973, p. 30.
22. Management Committee of SCITEC (J. B. Armstrong, M. P. Bachynski, L. Berlinguet, V. Douglas, P. A. Forsyth, J.-L. Meunier, W. G. McKay), contained in Science Council of Canada Special Study No. 25, December, 1972, p. 8.
23. Science Council of Canada Annual Report, 1972-73, p. 38.
24. Science Council of Canada, Special Study No. 25, *op. cit.*, p. 9.
25. Wilson, *op. cit.*,

APPENDIX

THOUGHTS FOR CONSIDERATION BY THE GOVERNING BODY OF AN INSTITUTE FOR RESEARCH ON PUBLIC POLICY IN CANADA

Ronald S. Ritchie

1. The Letters Patent of the Institute should define its purposes broadly, regardless of the initial breadth and number of the fields in which it may operate. The areas of concern to public policy cannot be narrowly confined nor clearly foreseen even for the near-term future. They are likely to touch on all fields of human knowledge. The Institute's future should not be circumscribed by too limited terms of reference.

2. Two general observations should be made about the Institute's choice of policy areas in which to work. First, the time focus of the Institute's research programs will be of critical importance to its long-run success. The Institute must focus its attention on the next five to ten years and beyond, not on this year, next year, or the year after. For decisions which must be made immediately or in the very short term, it is already too late for the kind of policy-oriented research which the Institute should have as its purpose. Should it be tempted into such fields regardless, it can be almost certain of weakening or destroying itself by uncalled for involvement in politically controversial situations in which its real contribution can be only minimal. Self discipline on this score will not limit its choice of projects unduly. Most of the policy areas which will be critical in the period five to ten years hence are already being actively discussed. The role of the Institute is to provide information and analyses which will improve the calibre of that discussion, thereby stimulating dialogue which will be helpful to eventual policy choices.

Second, the Institute should ensure that its studies have particular relevance to Canadian situations and Canadian needs. Its purpose will not be to add to the general fund of theoretical knowledge, but rather to improve understanding by Canadians and their governments of particular Canadian economic, social, and political problems, domestic or international. Additions to the sum total of theoretical knowledge will almost certainly come from the Institute's efforts, but usually as a by-product of its basic purposes.

Within these basic constraints, there are a number of broad areas of public policy concern to which the Institute could direct its efforts, and countless projects within each which it could undertake. The Institute will have to make choices, guided both by its judgment of the value of the contribution it might make in particular areas and the very important need during its early years to build its reputation on a solid foundation. It might, for instance, decide initially against foreign policy studies, both because other bodies, such as the Canadian Institute of International Affairs, are contributing in this field and because it might see little early hope of making a substantial contribution itself. Even in its early years, it would seem wise for the Institute to build up its competence in

areas such as regional economic disparity, the quality of the environment, the problems of native peoples, the determinants of productivity and growth (research, technology, education, and investment), and the complex of problems involved in urbanization, all of these in specifically Canadian terms. These topics and others are bound to be of continuing importance in Canada for at least the next decade, most of them far beyond that. The Institute could obviously not spread itself over all these fields initially, but once it has assembled a competent, truly multidisciplinary professional staff, whose efforts can be complemented by the work of outside consultants from the universities and elsewhere, it will have considerable flexibility to move among such policy fields.

There is one point which deserves special mention. In its Third Annual Review, the Economic Council of Canada pointed to the need for a body which would regularly deal with short-term developments in the Canadian economy. There has been general agreement among economists on the value of such a function and on the kind of contribution which short-term forecasts such as those of the National Institute in the United Kingdom or the National Planning Bureau in The Netherlands can make. While agreeing with the need, I believe that this would not be an appropriate task for the Institute to undertake. In its time focus and in its nature and requirements, this activity would differ substantially from the basic function of the Institute as proposed here. To be well done, it would require a sizeable group with highly specialized skills and interests, a group large enough to make some difference to the whole working atmosphere. It would also require continuing attention from the president and other directing staff of the Institute, diverting an important part of their efforts from the longer-term policy areas of the Institute's work. There is the added danger, as well, of unnecessary embroilment in current controversy over actions of the monetary authorities or the fiscal, monetary, and other policies of government affecting the short-term economic outlook. I would suggest that this whole activity might be better performed by another body. It is not an activity which is particularly compatible with the Institute's purposes.

3. The Institute may find it appropriate to aim at an in-house staff large enough to produce one-third to one-half of its research output. If its professional staff is smaller, it will provide an insufficient core to support a truly multidisciplinary research program. If it is too small, it will not be able to provide the orientation and the management skills upon which effective policy-oriented research programs must be built. These skills and interests must be provided from within the Institute. The kind of research management required must be learned. It is not likely to be provided by academics who participate in the Institute's research studies through part-time contributions to project efforts. The experience of the Rand Corporation has been that effective project directors are scarce and difficult to develop, but absolutely essential to the pace and the quality of the total research effort.

4. The most important determinant of the standing of the Institute and its staff with governments at all levels and with the academic, business, and professional communities will be the calibre of its work. While the Institute will probably only rarely take policy positions or accept responsibility for the conclusions of its studies, it must accept responsibility for the competence of the work, the analysis, and the writing. For this purpose, Brookings, Rand, and others have found essential the practice of having review committees or referees who study each manuscript carefully, pass judgments on it, and make suggestions. Such readers may come from outside or from the Institute's own staff (Rand stresses referee competence among its staff members and selects referees with an eye to promoting the multidisciplinary approach).

5. To the extent that there has been public policy research in Canada of a type which the Institute will undertake, it has largely been performed by university personnel, although seldom on a broad, organized, and sustained basis. Canada has not yet developed the kind of flow of personnel between the public service and the universities which exists in the United States. The supply of talent with both academic and public service backgrounds is, therefore, rather small in Canada at this time. In fact, the total supply of those interested in working full-time at policy-oriented research and equipped with some of the desired skills may be small. The Institute is likely to have to develop some of its own expertise.

It may be desirable for the Institute to embark deliberately on a long-term program for increasing the pool of talent oriented to and skilled in the techniques of policy research. For university personnel, some appointments to the Institute's staff, contract assignments as outside members of its project teams, post-doctoral research grants to be held at the Institute, and other forms of fellowship would all contribute to this end. For public service, business, and professional personnel, the Institute might serve as a base for the equivalent of sabbaticals or for particular research projects in which the individual or his employer share an interest with the Institute. The various programs undertaken by Brookings for both academic and public service personnel, as well as for business and professional groups, suggest a number of models.

6. To serve governments at all levels in Canada and to serve all the people of Canada, the Institute must have the capacity to work in both of Canada's official languages. This means that its published work will be in English or in French, depending on the subject or the author. It means that its research staff, its administrators, and its governing body will as a matter of course include both those whose mother tongue is English and those whose mother tongue is French. It would, however, be unfortunate if its bilingual character were to become a matter of formula representation rather than an unforced, natural reflection of Canada's two founding cultures.

7. Choosing the best location for the Institute may not be an easy task. To meet regional needs, it was suggested to me that the Institute might have two or more branches. Despite the relative ease and speed of travel and communication

now, this would seem unwise, at least for several years. Apart from questions of cost, which might not be decisive, there is the need for any multidisciplinary group to achieve a useful level of interaction and dialogue. This is likely to be difficult enough in the early stages and, as previously suggested, essentially impossible without a staff of minimum size in one place. Rather than have branches, it would seem preferable for the Institute to meet the need for regional links and knowledge by other means, including staffing policies, local consultation, local advisory groups, conferences and seminars, and the awarding of research fellowships to be held at the Institute.

There are a number of important factors to be taken into account in selecting a location for the Institute. As already mentioned in the report, there are sound reasons for locating close to a good university. In the early stages, before the Institute has been able to build up a library of its own, it will be important to have a location which gives relatively easy access to adequate library resources. Because there should be a constant flow of visitors to the Institute, and a good deal of travel by members of the Institute's own staff, easy access to good airline connections is desirable. From the standpoint of attracting the kinds of staff desired, location in or adjacent to a metropolitan centre may be preferable to location in a small and somewhat isolated community. From this standpoint, even climate and geography may be factors to be considered.

8. On the basis of what I saw and heard during the survey, I became impressed with the importance to the Institute of having suitable quarters planned for its use and owned by it. The Institute is intended to be permanent. It can be given the stamp of permanence, and an identity at the same time, by early provision of a suitable headquarters building. I would suggest that this might be an appropriate use (even on grounds of financial judgment) for a part of its endowment.

Rand Corporation provided itself with a headquarters building very early. Because of its contract relations with the Air Force and because of the standing of its board of directors, it was able to finance the major part of the original cost by a mortgage. The judgment of those concerned is that the early acquisition of its own headquarters facilities was an important and valuable step. Brookings owns its handsome and well-planned headquarters building on Massachusetts Avenue in Washington, D.C. It makes extremely effective working use of it, more so than would be possible in rented, general purpose office space. It has been able to finance it from the endowment it has built up over the years. Both the Hudson Institute and the Munich Institute have their own appropriate headquarters, although, in the case of the latter, title to the large, formely private house which serves the Institute is held by West Germany's federal government.

In all these cases, the fact of having their own distinctive working quarters contributes greatly, I became convinced, to establishing both the specialized working atmosphere appropriate to a public policy research institute and a desirable feeling of identity in the minds of staff and public alike. A public policy research institute is not a university, but its working atmosphere should

be closer to that of a university than of a bureaucracy. It can gain in effectiveness as well as in attraction to professional staff if it is housed in such a way as to contribute to at least a semi-academic environment.

9. The channels of communication which the Institute establishes will have much to do with its actual influence, and, therefore, with its success. Publication will undoubtedly be a major vehicle. While the calibre of the Institute's published research must gain the respect of the academic world, it will not, I trust, be directed primarily to academics. Its intended audience should rather be opinion leaders, public servants, and political leaders. If this is the audience, what the Institute publishes must appear, not in the esoteric language of scholars, but in language which speaks to decision makers, those who influence them, and those who influence public opinion.

The Institute will need to develop methods and forms of communication to reinforce the messages of its publications and to help keep its research activities related to actual needs. As Brookings has demonstrated, a deliberate, continuous effort at informal communications by its president and his supporting staff with public servants and political leaders can be mutually advantageous.

Seminars and conferences which bring public servants, academics, business, labour, and professional leaders into closer contact with the Institute's work and with its purposes can be equally useful. Only if the Institute's work is competent, relevant, and understood can it be valuable.

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A PLAN FOR ACTION

In the past five years many studies on science policy have been published in Canada and many organizations and individuals have taken part in the extensive debate that has followed. Some people deplored this detailed examination, arguing that continual questioning of the status quo created a climate of uncertainty that weakened the prestige of policy makers and hurt the morale of their staffs. Others, impatient for action, contended that it was futile and only led to paralysis.

The Committee disagrees. We are convinced that these studies and the debate they provoked were the essential first step toward a plan of action. We believe Canada's past failure to formulate a consistent and realistic science policy stemmed mainly from the fact that too many decisions were hidden or taken without adequate examination or consideration of their impact. Moreover, the activity of these five years has helped to improve our collective knowledge of science policy issues and to develop a consensus that would not have been reached otherwise. It has also already produced tangible results that we need hardly enumerate here. Several government departments and agencies have begun to respond to our suggestions and recommendations. Even the climate of uncertainty created a flexibility that has permitted more desirable changes than could have been envisaged a few years ago.

THE IMPLEMENTATION OF THE REORGANIZATION PLAN

The Committee agrees, however, that the time has come to implement a comprehensive plan of action. This should be realistic, but it must be

bold. We recall a quotation from Prof. E. Miles of Princeton University, printed in Volume 2:

> Reorganizations are not usually sufficiently imaginative and drastic to cope with tomorrow's problems—only with the worst of today's problems. Rarely is a major reorganization pattern developed and installed in a federal department or agency which is based on meeting future needs instead of merely alleviating yesterday's and today's pains. In consequence, by the time the typical reorganization is put into effect, it is already out of date.[1]

We hope the government will avoid this danger and instead use the unique opportunity created by the present condition of flexibility to implement a plan to meet future needs rather than cure yesterday's pains. Two main tasks are involved: the government must implement a major administrative reorganization, and it must design a detailed decision model and apply it with care to make sure science policy remains dynamic and forward looking.

Decisions on reorganization must come first because the nature of the decision model will largely depend on the structural changes made in the government scientific establishment. In the last two volumes of our report we have submitted an overall reorganization plan. Some critics have said—and will undoubtedly continue to argue—that this plan is too radical, that it is unduly complicated, confusing, and burdensome because it involves the creation of various foundations, boards, institutes, and committees. (We wonder whether such critics despise the complexity of their own central nervous system because it is more complex than that of lower forms of life.)

In reality, what is this "radical" plan? We have applied the principle that major objectives should determine strategies and organizational structures. We have also accepted the view that institutions serving incompatible objectives or fulfilling partial missions in isolation can hardly be successful. In our report, we have concentrated on two main objectives. The first is to improve the flow of industrial innovations, mainly in the manufacturing and commercial service sectors. We have assigned this broad but homogeneous mission mainly to a strengthened Department of Industry, Trade and Commerce, which would be served by specialized agencies designed to support various stages of the innovation process. This organizational grouping around a common objective and concentrated in a single department should simplify the decision-making process and give it more flexibility and efficiency.

The second major objective is to achieve excellence in basic research. This is another broad but homogeneous mission, which we have assigned to the Secretary of State Department to which a group of specialized but intimately related foundations and institutes would report. Here again, we suggest, is a simplified and more efficient arrangement that should

ensure consistent policies, operating procedures, and reward systems and conduce to a vigorous basic science in Canada.

By focussing our reorganizational plan on homogeneous missions in compact frameworks, we feel we have substantially simplified the problems of effective decision-making, of determining the specific goals and actions required to achieve the major objectives, and, most importantly, of providing appropriate working environments and a sense of motivation for the staff of the proposed agencies. We believe our plan will reduce both the need for co-ordinating mechanisms and delays in selecting priorities and alternative solutions.

Within these main organizational groupings we have attempted to identify the specific needs of an effective science policy and assign the responsibility for meeting each need to a specialized agency whenever the scale of operations justified it. Inevitably this will mean the creation of more government agencies but there should be less fragmentation at the level of the small unit. This is exactly what specialization should mean: less rather than more confusion, a simpler definition of functions at the operational level, a greater chance for agencies to accomplish their missions satisfactorily, and a better basis for the central machinery to appraise and make recommendations for improving their performance.

Our proposals for basic research institutes and foundations provide for supervisory boards to set overall objectives and administrative policies and to maintain liaison with other organizations in the public and private sectors. For the same reason, we have recommended a single direction for all government laboratories serving the needs of manufacturing industries and the commercial service sector. We have suggested integrated and co-ordinating mechanisms between departments and agencies when we felt them necessary; we hope and believe they will mainly be based on the ability to contribute to policy formulation and implementation rather than on delaying tactics intended to preserve vested interests. More importantly, we have provided for a strong central machinery with the power to oversee the scientific activities of individual departments and agencies. And we could easily give other illustrations to show that our proposals should create less fragmentation and better integration, and that we propose specialization whenever possible and integration when desirable to obtain a homogeneous mission and reduce fragmentation of responsibility.

We wish now to focus attention on three major points, which contain the essence of our message. They concern the new roles we have assigned to the Ministry of State for Science and Technology, the organizational structure best reflecting the complex innovation process, and the new mission of the Department of Industry, Trade and Commerce.

1. *The new roles of MOSST*

The most crucial recommendation in the whole report describes the special review and assessment procedure for the science budget and the specific role of the Ministry of State for Science and Technology. We have given more careful thought to this issue than to any other because it is the foundation of our plan of reorganization. We know the objections that will be raised to the central machinery for science policy outlined in Chapter 20; but we cannot accept them.

It is undoubtedly important to reform existing departments and agencies, to create new specialized institutions when necessary, and to ensure that they can make micro decisions effectively. But in a sense the beneficial effect of these changes will be marginal unless there is a strong focus at the centre. We are firmly convinced that the government will not be in a position to develop the dynamic, coherent, and balanced science policy the country needs if MOSST's role is limited to formulating new policies and advising departments and agencies in the preparation of their scientific programs.

This advisory function will not work in the long run. Departments and agencies do not have to accept this outside advice and will come to resent it. The ministry will not be able to keep competent people to play a role that is bound to become increasingly frustrating and, in the process, will lose its credibility and usefulness. The government will thus have missed another chance for meaningful supervision of its science policies. This regrettable development is now taking place in the United States and Britain.

It would be equally undesirable to give the Ministry of State for Science and Technology the responsibility for operating agencies.

We have closely examined the possibility of the ministry's serving Treasury Board in an advisory capacity and have rejected it. It has the same inherent frustrating features as the other system, with additional disadvantages of its own. It would cut the ministry off from departments and agencies and prevent it from discussing their scientific programs directly with them. This could considerably reduce the quality of its assessments. Moreover, Treasury Board would not be discharging its responsibilities properly if it accepted the ministry's advice at face value. It would need specialized staff to appraise this advice and in many cases would have to start a new round of discussions with departments or agencies before reaching a final decision. This would make the budgetary review process cumbersome, roundabout, and frustrating for all concerned.

Our considered opinion is that a special review and assessment procedure is needed for the science budget and that it should be placed under the authority of the ministry and of an interministerial committee on

science and technology. Once the science budget had been determined it would be submitted as a package to Treasury Board, which would consider it in the light of the government's overall budgetary constraints. This system is not as revolutionary as some people might think. Five years of hearings and studies on science policy matters have convinced us there is no suitable alternative that can lead to a coherent and dynamic science policy. The new procedure would require competent and dedicated people who feel they are playing a meaningful role, but not a large staff.

In implementing this plan of action, we urge the government to give first priority to this issue. Its early decision on the new role of the ministry and the creation of a new cabinet committee on science and technology will have a direct impact on other aspects of the reorganization plan and, if our recommendations are accepted, would make the implementation of the plan easier and more orderly. A particular advantage of our proposals here is that they do not require new legislation and can therefore be applied quickly. The government will have to be bold and realistic in dealing with this central issue. We hope it will not persist in applying past models that have failed to meet the country's needs. We hope it will resist bureaucratic objections. The government has the opportunity to establish what should be the best possible central machinery for science policy. This opportunity may not offer itself again for many years—and then it may be too late.

2. *Organization for innovation*

Most of the criticisms the Committee has received include the contention that success in technological innovation requires a continuous sequence starting with basic research and ending with the launching of the innovation. We have been criticized for rejecting that view and recommending a loose coupling between basic research and applied research and other scientific and engineering activities.

It must be clear that we have not recommended a *complete* organizational separation between basic and applied research. When we proposed the creation of three government institutes, for the physical sciences, the life sciences, and the social sciences, we indicated that these agencies should be responsible for "*most* basic research activities of the Canadian government." We did not exclude the possibility that the institutes would perform some applied research or that mission-oriented departments and agencies would do some basic research on a residual basis. For us it was a question of emphasis, inspired by the need for specialization and integration. Moreover, we suggested that "a *substantial* portion of the

work of the institutes be performed at the request of government agencies and private firms on a fee basis," thus providing for a strong and effective coupling between basic research and practical missions, one that combines freedom and relevance.

When we recommended the creation of three foundations, for the physical sciences, the life sciences, and the social sciences, we indicated that they should be "responsible *mainly* for the development of a capacity for and the support of curiosity-oriented basic research in universities and similar institutions." We added that any assistance the foundations provided to scientific surveys and applied research should "be residual and available only in areas where there were no other specific federal agencies." Again it was a question of emphasis based on a proper division of labour, because mission-oriented agencies should be in a better position to know the need for scientific surveys and applied research in their sectors than the foundations.

When our recommendations are properly interpreted, therefore, they provide for what all studies show to be the appropriate relationship between basic and applied research—not a complete separation as some have claimed. That does not mean, however, that all activities relating to the innovation process should be kept together organizationally: the separations should be made where empirical evidence shows them to be desirable. Most people agree that universities are the ideal location for curiosity-oriented research. They also accept that the development work preceding an industrial innovation should be done by individual firms. But if all the activities related to the innovation process were inseparable (as proponents of the continuous-spectrum theory of innovation imply) this would mean that all scientific activities following basic research should take place in universities or, alternatively, that all activities preceding development work should be done by industry. Neither of these alternatives is realistic.

The scientific activities associated with the innovation process must be grouped appropriately for administration and performed where they are likely to produce optimum results. This division must remain flexible to cover grey areas and provide effective links so that the separation effected still permits the proper organizational or spatial coupling.

There are two schools of thought on flexible separation. Some contend that basic research should not be dissociated from applied research, but then accept, at least implicity, that applied research should be separated from all phases of development. Others argue that mission-oriented applied research should be closely associated with development, but would like basic research to be somewhat isolated.

The Committee regards the choice between these two schools as too important to be left to old myths, vested interests, and individual prejudices. It must be made in the light of serious studies on the conditions for

success in the innovation game. We have studied all the empirical analyses we could uncover and our findings are in Chapter 12 of Volume 2 and Chapter 21 of this volume. All the evidence available to us shows that fruitful basic research is often motivated by pure intellectual curiosity; that in most cases it is not an essential condition of success in innovation; that its links with the launching of new products or processes are remote and take many years to appear. It indicates that the innovation model of a continuous spectrum from basic research through applied research and development to innovation is a myth that can grossly distort science policy decisions and organizational structures.[2]

Unfortunately this myth has been found useful by many basic scientists. By choice or necessity, they have publicly proclaimed practical outputs as justification for the public funding of basic science. As Sir Peter Medawar points out:

> The champions of pure learning have in one respect brought today's mercenary reappraisal of their activities upon themselves: they have attempted to justify academic science by calling attention to the useful or financially profitable advances that have grown unpredictably out of their activities in the past. If they themselves are prepared to evaluate their work by a scale calibrated in dollars, they should not resent it if others do the same.[3]

If curiosity-oriented basic research is threatened today, as some claim it is in the United States and Britain, the managers of basic research organizations might reflect on their share of the responsibility for it.

In Canada the myth was imported from Britain after World War I and gave rise to the model described in Volume 1. As the Committee has shown, the model never worked. Members of the scientific community and engineering organizations should not transmit the myth as if it were an unquestionable article of faith. We are convinced that if they read the available empirical studies with an open mind, they will change their views and come to accept the separation we have suggested. They will agree with Dr. Solandt's final statement as chairman of the Science Council, which we repeat here:

> NRC's traditional strength has rested on the outstanding performance of a number of gifted basic researchers, who were given both the resources and the freedom to pursue their scientific interests in directions of their own choosing. While this has given Canada a strength in some areas of basic research, the administrative intermingling of applied research groups with the basic research groups, in an organization attuned to creating the conditions necessary for good basic research, has probably been a major factor in distracting the applied groups from their primary role of supporting industry.[4]

We remain convinced that the major but specific tasks of the proposed institutes and foundations are fully justified. We insist that the mandate

of these new agencies should put a clear emphasis on their main mission, to carry out or support basic research.

This does not mean that more imaginative and appropriate interaction between basic research and the various phases of the innovation process should not be attempted. We hope the contractual arrangements between mission-oriented departments and agencies and the three institutes will have that effect. We also agree with Dr. Steacie that "long-term applied research with no specific objective" should be closely associated, for organizational purposes, with basic research.

The government's decision to create the institutes and foundations should be taken early in the reorganization because other important aspects of the plan depend on it.

3. *The new mission of IT&C*

An immediate consequence of that decision should be the establishment of the Canadian Industrial Laboratories Corporation under the auspices of the Department of Industry, Trade and Commerce. We have suggested that the corporation should include not only the industrial laboratories operated by NRC but also laboratories involved with the processing and metallurgical industries that are currently the responsibility of the Department of Energy, Mines and Resources, the forest products laboratories now located in the Department of the Environment, the Food Research Institute in the Department of Agriculture, and, most likely, certain establishments now operated by the Defence Research Board. We still believe this corporation could play a useful role, even within the framework of the contracting-out policy.

We also suggest that about half the activities of the new organization should be financed by contracts from industry. This would ensure that its work would be relevant to real industrial needs.

The Committee has assigned other important functions and agencies to the Department of Industry, Trade and Commerce. These include the integration of industrial R&D incentive grants into a single flexible program; operating responsibility for information transfer and technological forecasts in the field of industrial innovation; the Canadian Innovation Bank; the establishment of industrial task forces; and the Office of Industrial Reorganization. These functions and institutions are needed to develop a dynamic and comprehensive industrial strategy, which the manufacturing sector of the Canadian economy in particular needs so urgently.

A strong initiative from the department becomes more necessary with every passing day. In several countries, improved technological compe-

tence through the generation and transfer of technology is more and more considered a prerequisite to a healthy trading position and a growing national economy. There are also signs that the U.S.A. may become less generous in permitting other countries easy access to its latest technology through licensing or the foreign subsidiaries of its multinational corporations. Increasingly Canadian industry will have to specialize and rationalize; increasingly its technology will need to match our main international competitors'.

The Committee cannot say that the department has provided strong leadership. Our disappointment should not be interpreted, however, as criticism of the minister and his staff, but rather of the organizational arrangements that followed the amalgamation of the Department of Industry with the Department of Trade and Commerce. In the new department senior management has been unable to devote the time required to science and technology or industrial development issues because of the pressures of its heavy responsibilities for trade matters. In short, the fusion of the two departments was at the expense of the industrial mission.

In the former Department of Industry, the chief scientific adviser reported directly to the deputy minister and had a rank equivalent to assistant deputy minister, which enabled him to deal with other departments at a senior level. In the combined department the chief scientific adviser for industry first became responsible to a senior assistant deputy minister and later was placed three levels below the deputy minister, which further reduced his influence in the government service and his contacts with industry.

The recent reorganization of the department, which involved the appointment of a senior assistant deputy minister responsible for industrial development, including industrial policy and science and technology policies, is a step in the right direction. However, even with these changes, the heavy demands of the trade responsibilities on the deputy minister's time and energy will continue to cause him to neglect technology and innovation policies. This cannot be tolerated: a dynamic domestic industrial strategy is the essential complement to a successful trade policy. Indeed, this is undoubtedly what led to the unification of the former Department of Industry and Department of Trade and Commerce, and it is still justified today. But the time has come to restore a better balance. That is why we recommend the appointment of a deputy minister for industry. This post, with all the new responsibilities it would involve, will require special skills and competence from the appointee, including a good background of industrial experience.

The Committee realizes that new legislation would be required for such an appointement, which might take some time to introduce. Serious consideration should be given, meanwhile, to the appointment of an

appropriately experienced man to do the preliminary planning required by our recommendations. He should eventually become the senior assistant deputy minister for technology and innovation, responsible for making the changes in organization required by our proposals.

These are the three most crucial areas of our reorganization proposals.

The Ministry of State for Science and Technology, with its new mandate, should become the catalyst of this broad operation and prepare the overall plan, in consultation with the departments and agencies concerned. Once proper consultations have been held, decisions should be made. By the end of 1973 the ministry should be ready to submit its plan to Cabinet as a package. The government must be able to see the complete picture before reaching a decision. Once the overall plan has been approved, the Prime Minister should make it public, at least in its broad features, so as to give it his full and formal backing. This would be the first time that a complete and *coherent* chart had been issued for future government involvement in innovation, technology, and science.

The Ministry of State for Science and Technology should also have the main responsibility for implementing the plan under the direction of the Interministerial Committee on Science and Technology. In certain areas this plan will create organizational difficulties while agencies struggle to preserve as many of their present prerogatives or acquire as many new ones as they can. Without an impartial centre of initiative and leadership, important changes may be carried out badly or unduly delayed as a result of what Donald A. Schon calls "dynamic conservatism."

The ministry should divide the individual items of the plan into two categories, those that require legislation and those that do not. In many cases the government will be able to take action simply by making administrative decisions or passing orders-in-council. In those cases action should be taken as quickly as possible. But other parts of the plan will require amendments to existing acts or new pieces of legislation. Since it would require a great deal of Parliament's time to introduce the legislation piecemeal; since individually none of the parts has a high immediate priority; and since the significance and some of the merits of the reorganization blueprint appear only when it can be viewed in its totality, the Committee suggests that the Ministry of State for Science and Technology should prepare an omnibus bill of all the legislative changes and additions required by the plan. It should be introduced as early as possible to give parliamentarians ample time to study it. We do not believe it would give rise to a partisan debate in Parliament, although it should be carefully considered by the appropriate committees of the Senate and House of Commons, nor would we expect the bill to take much of the time of Parliament as a whole.

THE NEED FOR A DECISION MODEL

The Ministry of State for Science and Technology should also undertake to design and apply a decision model for science policy, especially in the area of mission-oriented programs.

It is clear that as the world around us changes, science policy must change; that is, it must be dynamic. A static policy would be ephemeral; in a short time, new imbalances in the national effort and rigidities in our institutions would arise just as they have in the past. Science policy must anticipate changes in the environment and respond to them in such a way that Canada can best use technology and science to achieve full development and allow us to live a better life.

The Committee believes that normative planning, which links action with desired objectives, is right for the formulation of science policy. The normative approach will provide the organization structure and the processes needed to assess who should do what, which skills are required, and what information is needed to make the decision system work efficiently.

Planning systems have two fundamental purposes: to select the best of several alternative courses of action, to provide a framework for daily decisions in a complex organization. All actions, whether formally recorded in plans or not, are based on forecasts about their future consequences. The basis of forecasts may vary from the assumption of stability to the expectation of change. The pace of change itself is an important factor in determining the need for planning. If an absolutely stable environment existed, planning would be less necessary and much easier. In periods of rapid change, the only thing we can be certain of is that the future will be different from the past; then it becomes much more necessary to forecast and plan than in periods of stability. Forecasting the future is at best hazardous, but if the rate of change is high, the one sure way to be wrong is to assume stability or ignore change. Thus forecasting and planning, paradoxically, become more essential as they become more difficult. That happens when, as today, the environment is in flux. This is notably true of the world of innovation, technology, and science.

There is another reason for developing a planning system for science policy. The job of co-ordinating human effort expands at a geometric rate as an organization's staff grows arithmetically and the number of possible human interfaces and opinions increases. The task of arriving at a consensus about the organization's direction and each individual's contribution is complex in a single department, but when many large departments are involved, people can only make a coherent effort when they clearly understand the organization's goals and their role within it—and a

planning system is the only process capable of providing the integrating framework needed to do that.

If the ministry is given the responsibility we think it should have, it will need to build just such a system. In doing so, it should not merely adopt Treasury Board's planning, programming, and budgeting system. This has certainly introduced the first steps toward management and operational planning but its time horizon is too short and it lacks some of the elements required in a decision model for science policy, specifically elements at the strategic level. Moreover, the Treasury Board's system is not integrated; the common base of objectives and national concerns is missing. Each government department and agency develops its own short-term plans in isolation, according to its own management's perceptions of what is important for Canada.

In Volume 2 we suggested that forecasts of alternative futures should be developed for the years 1985 and 2000 and that the time frame for science policy planning should be 15 years. We believe a long time span is necessary for a strategic plan involving technology and science and providing for action objectives, statements of priorities, ways and means, and broad scenarios. This long-term plan should guide the next level of planning, the five-year management plan we also proposed in Volume 2. It frequently takes five years for the results of a newly initiated technological or scientific program to become measurable. (The present three-year management planning system used by Treasury Board is too short, at least for scientific activities.) In turn, the five-year plan would help to determine the operational plan that would be included in each year's science budget.

The comprehensive planning system the Committee has in mind would provide a common base of objectives and a common framework for the integrated decisions that are needed to formulate and implement a dynamic and coherent science policy. The process is conceptually simple: first, develop a consensus among top decision-makers about *what* to do, and secondly, create detailed plans describing *how* it will be done. Both the *what* and the *how* must be based on a forecast of the future (or alternative futures with alternative plans).

The specific long-term objectives have a quantitative dimension and a time horizon; that is, they describe *what* the government wants to achieve *by when*. This first stage is crucial. Objectives are the foundation of a planning system. Without them there is no star to steer by, no guidance on what measures of effectiveness would be appropriate, no way of determining whether our actions are taking us where we want to go. Without them action plans tend to conflict with each other or go off in all directions at once, instead of being designed to achieve specified goals.

The Ministry of State for Science and Technology should use this broad perspective and methodology to develop its own decision model. Once the basic long-term objectives have been determined and turned into a strategic plan for science policy, the ministry should determine the current situation so that, in co-operation with departments and agencies, it can judge the best route to the goals. It should develop statements on the current status of the institutions and processes that can be controlled or influenced. These should include a description of the organizations at the government's command and the processes used to convert inputs to outputs (people, funding, products, services, etc.). They should describe the environment in which these institutions and processes operate as well as the key variables that measure their performance. Strengths and weaknesses should be assessed to evaluate how effectively each institution and process contributes to advancement toward the objectives.

The next step is to project the status of our institutions, programs, and processes to the appropriate time horizon and evaluate the gap between objectives and performance if no changes are made. If the projection indicates that objectives will not be achieved, alternative courses of action must be generated. These must be subjected to cost/benefit analysis which may range from quantitative to qualitative, from rough to refined, depending on the time horizon and the nature of the alternatives. From these analyses the advantages and disadvantages of each course of action will be determined. A portfolio of policies, strategies, and programs to achieve the objectives will be selected and then translated to shorter time frames appropriate to the budget process (normally one year). These commit resources and implement programs and control procedures designed to measure the attainment of progress against the key variables and identified annual goals. The year's progress would then be evaluated, before the decision cycle is repeated.

The plan should be scanned for variances at an appropriate frequency. When conditions in the environment and in institutions do not change substantially from the projections, no change may be necessary. But follow-on control and evaluation is essential.

This is a brief, general description of the kind of planning system and decision model that we think the Ministry of State for Science and Technology should develop in the near future. To fulfill this challenging responsibility, the ministry should acquire the services of competent planners and management scientists. The Committee gives a high priority to this operation. Even with a good decision model the ministry will make mistakes. It will not always be able to detect opportunities and threats in time or discover gaps, duplication, imbalances, and poor performance in the government scientific establishment. Without a decision model, however, it would be in a much worse position to accomplish its complex and delicate mission; it would be walking blindfolded.

So the Committee wants to underline two specific recommendations contained in Volume 2.

We suggested "that the Ministry of State for Science and Technology be made responsible for keeping a national R&D inventory and . . . for developing a national audit of current R&D programs and projects being supported by public funds."[5] These are essential elements of a sound decision model. They are necessary to identify strengths and weaknesses, and to correlate specific activities with national concerns.

This specific proposal was made in the context of a broader recommendation suggesting "that the Canadian government and Parliament adopt an overall plan for the Seventies for science and technology, based on longer-term projections and overall national R&D targets, and that the procedures and organization of the planning, programming, and budgeting system be improved to provide a better assessment of the output of R&D activities and a better basis for determining annual appropriations for the financing of such activities." We also proposed "that by 1980 the approach be formalized in a framework of successive five-year plans."[6] We now recommend that these responsibilities be assigned to the ministry as the main focus of a new central machinery for science policy, but under the supervision and control of the proposed Interministerial Committee on Science and Technology.

CONCLUSION

The Committee believes that the government now has all the elements needed to proclaim a new charter for the organization and support of industrial innovation, technology, and science in Canada. After several years of analysis, the time has now come for decision and action.

The Ministry of State for Science and Technology, the Science Council, and the Committee have, in their different ways and within a broad consensus, helped to prepare the overall design and the detailed blueprint. The government must now act as quickly as possible to eliminate uncertainty and provide Canada with the federal institutions and policies so badly needed to face the challenges posed by technology and science in the 1970s and in the long-term future. Let us make 1973 the year of decision on the broad and vital issues of science policy. A year of action, not reaction.

NOTES AND REFERENCES

1. *Targets and Strategies for the Seventies, op. cit.*, p. 605; from *Committee on Government Operations*, U.S. Congress, January 28, 1968.
2. See Chapter 21.
3. Sir Peter Medawar, "The Pure Science", *The New York Times*, June 24, 1973, p. 15.
4. Science Council of Canada, Annual Report, 1971-72, pp. 46-47.
5. *Targets and Strategies for the Seventies, op. cit.*, p. 413.
6. Ibid., p. 410.

ANNEX A

SURVEY OF RESPONSE TO RECOMMENDATIONS ON SCIENCE POLICY TARGETS AND STRATEGY

INTRODUCTION

The Committee has already indicated its satisfaction with the response Volume 2 has generated. More than a year after its publication it is still widely quoted and discussed, not only in Canada but abroad. At the beginning of our inquiry, we said that one of the main objectives was to provide a public forum where the main issues raised by science policy could be reviewed and discussed. That goal has been fully met.

Although we do not believe in "paralysis by analysis" and are convinced the time has now come for the government to act, we feel we owe it to the groups that studied our recommendations to publicize their main comments and let them know our reactions. This is why in Chapter 21 we reviewed most of the specific proposals in Volume 2 related to the reorganization of departments and agencies.

For the same reason this annex reviews the proposals on targets and strategies made in Volume 2 in the light of the comments submitted by private individuals and groups, although this third volume is devoted to government organization for science policy. As in Chapter 21 we cannot refer specifically to all the briefs. Some were sent directly to the Ministry of State for Science and Technology or SCITEC and we have not seen them. A number repeat various points. And while we favour dialogue, we do not intend to engage in a fight with those few critics who appear to be more interested in making unsubstantiated accusations than in presenting reasoned arguments or constructive proposals.

We give one example, the brief of the science faculty of the University of New Brunswick, to show what we mean. This is the brief that ended with the words:

> . . . We have no choice but to state that the Senate Committee Report and its recommendations constitute a great disservice to science, to the universities and to Canada.[1]

The section of the brief entitled "Implications of the Report for Students" states:

> The Senate Committee obviously recognizes only one function for university science and that is the manpower training function. The Committee would presumably request the Federal and Provincial Governments to project the number of engineers and scientists of various disciplines that would be required in any given year and then allow the universities to train that number and no more. We believe that such a system is unworkable and unjust.[2]

To support this allegation the brief refers to our report:

> First, it is not enough to rely on the inclinations of students, who if left to themselves might overcrowd some professions and neglect others.[3]

But it does not quote the next sentence, which clearly expresses what the Committee had in mind:

> Programs of scholarships and fellowships can serve to correct imbalances and must be determined by the future needs of the R&D effort.

This is a far cry from advocating, as the brief alleges, "a system of enrolment quotas."

Here is another illustration of the lack of objectivity of the University of New Brunswick science faculty brief:

> . . . However, what the essence of the report is reduced to is that government should provide greater financial aid to industry at the expense of the universities.[4]

The Committee indicated that according to the best estimates available, Canada had spent $205 million on basic research in 1967 and we recommended that this amount be raised to $475 million by 1980. We also stated:

> The targets proposed in this volume for basic research and the economic innovative process involving industry would amount to about 70 per cent of the proposed total R&D expenditures by 1980. These targets would therefore leave a large portion of the proposed total expenditures for the social innovation process by the end of the present decade. We feel that the national effort in this area should be substantially increased because of past neglect and the urgent need to improve the efficiency and control the rising costs of our social systems in such sectors as health care, pollution abatement, education, social security, housing and urban living, crime prevention, and criminal rehabilitation.[5]

We have quoted at some length to show that while this kind of childish brief and biased comments may alleviate the frustrations of some scientists they do very little to develop a good science policy for Canada. Fortunately, we have received few briefs of such dubious quality.

As in Chapter 21, our detailed review is based mainly on comments from the largest or most representative private organizations. We refer specifically to the Official Response Committee and the enlarged National Response Committee answers to the SCITEC questionnaire. As is indicated in Annex B, these two committees approved most of our recommendations by a majority vote. The average vote in favour of the specific recommendations reviewed in this annex was 70 per cent. Of these 27 specific proposals, only 2 did not get at least 50 per cent support from the two committees: the first one dealt with the priority to be given to basic research in the social sciences in the 1970s, the second called for a limit to government in-house industrially-oriented R&D until these activities had been thoroughly reviewed. We attach particular importance to these two responses because they indicate the views of individual scientists and engineers, expressed by a secret vote.

TARGETS AND PLANNING

There has been considerable controversy and, we think, misunderstanding over the meaning of the targets to be used in the planning of an improved national R&D effort.

The need to set targets and to plan and evaluate the performance of the system designed to meet them is becoming apparent to all. We recommend that 2.5 per cent of the gross national product be devoted to the support of science, technology, and innovation in Canada by 1980. The Canadian Electrical Manufacturers' Association (CEMA), however, was concerned that the targets were set by the Committee "without any relationship to the needs for implementing industry strategies and attaining national goals."[6] The Electronic Industries Association of Canada (EIAC) expressed "considerable support" for the recommendation but pointed out that R&D expenditures are not a goal in themselves.[7] The Association of Professional Engineers of Ontario (APEO) stated that "for planning expenditures at this time, $2\frac{1}{2}\%$ of the GNP is an acceptable target," but "it will not have the desired effect to merely pump more funds in R&D generally."[8] The Canadian Chemical Producers' Association (CCPA) thought that "of all the recommendations of the report this has been most quoted out of context."[9]

While industrial groups generally accepted that 10 per cent of substantially increased national R&D expenditures should be devoted to basic

research, some scientists thought the target too small. This reaction was to be expected. A more surprising attitude was that of industry toward our proposal that by 1980 "the R&D activities performed by the industrial sector . . . represent a maximum of about 60 per cent of the national R&D effort." The argument that the proposed target could not be attained was understandable. But the EIAC, after giving "almost total support to this recommendation," argued that the goal was arbitrary and that "the report gives no clear indication of how such a target is to be achieved."[10] (On the contrary, the Committee believes that if its recommendations on industrial R&D and innovation were implemented as a package, they would greatly help in reaching the target over the years.) The Canadian Manufacturers' Association (CMA) went further and indicated that it could not accept a target in this area.[11]

The objections raised against the overall and specific targets can be summarized in three points:

1. It is undesirable to propose targets, specially for R&D financed by industry, because such activities are not an end in themselves and their level should be determined by the profitability of industry.
2. The targets suggested by the Committee are arbitrary.
3. There would be a substantial waste of money in trying to reach them by 1980.

We now examine each of these objections:

1. The Committee made it clear in Volume 2 that it did not view the national R&D effort as an end in itself. Indeed, we indicated in Chapter 12 that scientific activities should serve national goals and we concluded: "The basic objectives of science policy are cultural enrichment, economic growth, and public welfare."[12] However, the fact that scientific activities are means does not imply that their level should be determined at random or derived from the short-term financial situation of governments or industry. On the contrary, people who refuse targets for planning purposes are precisely those who implicitly and wrongly treat scientific activities as an end rather than as a tool.

Unfortunately this is another myth spread widely in Canada, especially in industry. The Chemical Institute of Canada stated: "If Canadian manufacturing is profitable, research may flourish; however, research alone cannot assure profitability in industry."[13] This attitude is revealed in many briefs we received. As we said in Chapter 15, it views research as an effect rather than a cause of profitability, as conspicuous consumption carried out when business is prosperous rather than as a source of growth and an investment required for survival and expansion.

We are disappointed to see that this fallacy is still propagated in spite of the empirical evidence we presented in Chapter 15. Of course "research alone cannot assure profitability in industry." We have said

repeatedly that it should be practical enough to lead to successful innovations, and that the private and public environment must be favourable. We would like to add evidence to show that in countries with a public environment similar to Canada's, R&D expenditures are an important factor in growth.

In February 1971 the National Science Foundation published a symposium on R&D and growth with contributions from the best American experts. According to Leonard L. Lederman:

> Research to date seeking to measure this relationship (at the level of the firm, the industry and the whole economy) points in a single direction—the contribution of R&D to economic growth/productivity is positive, significant and high.[14]

Edwin Mansfield observes:

> These studies rely on the results of several econometric investigations that indicate that for industries and fields under investigation, the marginal rate of return from an investment in research and development has been very high.[15]

Zvi Grilliches states:

> Investment in research, both private and public, has clearly been one of the major sources of growth in output per man in this century. It has been a good investment both in the sense that it yielded a positive rate of return, and in the sense that this rate of return has been as good and often better than the rate of return on other private and public investments.[16]

William Fellner concludes:

> *All* reasonable ways of looking at the matter lead to the conclusion that the rates of return are very high as compared to usual estimates of rates of return on capital formation.[17]

Thus, research is not an end in itself or an activity that should flourish only when business is profitable. It is an important cause of prosperity and growth, a good investment yielding high rates of return. Canadian industry should accept this conclusion from growing empirical evidence, abandon its false conception of research as conspicuous consumption, and stop blaming the government for its own poor R&D performance. This is crucial for the future of the economy.

This does not mean that any kind of research, under any kind of management, will yield high returns. In this area as in others there are specific conditions for success that must be met. Here again, empirical investigations are helping to identify the requirements. It is obvious, for instance, that R&D expenditures, like other outlays, are subject to the law of increasing and diminishing returns. Between these two phases, there is an optimum level for each firm, industry, or country. Thus, contrary to what has been asserted by some of our critics, it is desirable

to identify this optimum level and select it as a target. To reject this concept is to leave the determination of the R&D effort to chance.

2. As for the allegation that the targets we proposed were arbitrary, we readily agree that we did not have the data required to identify the optimum level of the national R&D effort directly. We had to rely on an indirect method based on international comparisons. We maintain, however, that this approach produces a valid national indicator, just as innovative firms look at what their competitors are doing before determining the size of their own R&D effort.

The level of national R&D expenditures and their distribution between sectors can be properly assessed in an international perspective. As we have shown, the results of basic research constitute an easily accessible global pool. This means that beyond a certain minimum enabling a country to benefit from that pool—which is relatively low—the national effort devoted to basic research is an international obligation and should be determined roughly by comparison with the contributions of countries of similar wealth. On that basis, and on the data available to us, we suggested that 10 per cent of the overall R&D expenditures would be fully sufficient to meet Canada's needs and international obligation, provided of course that quality rather than quantity were emphasized.

On the question of R&D leading to industrial innovations, we also observed that Canada faced an international technological race. We suggested that the nation should initiate more successful industrial innovations and for this purpose devote a share of R&D comparable to other industrially advanced countries'. On that basis, we suggested 60 per cent was far from exaggerated as a broad guideline since in 1967 the business sector performed at least 65 per cent of total R&D in six of the nine countries compared with Canada.

By the same reasoning we determined a target for the share of GNP to be devoted to all R&D. In 1967, most other industrialized countries had reached or exceeded a ratio of 2 per cent and were planning to increase it. We concluded that Canada should continue to improve its effort in the area of basic research and, in particular, participate more actively in the international technological race. We recommended a target of 2.5 per cent to be reached by 1980, which, on the basis of international comparisons, could hardly be called excessive.

Thus we persist in believing the approach we followed in selecting overall and specific targets for the Canadian R&D effort was not arbitrary. On the contrary, in the absence of the data required to measure the optimum level of R&D expenditures directly, we suggest that comparisons with countries with a high innovative performance represent the best indirect yardstick available to determine desirable targets for R&D in Canada.

3. Finally, the Committee has been told that its targets, especially that for industrial R&D, were unrealistic and would involve a great waste of money if the country attempted to reach them by 1980.

In Volume 2 we ourselves said of the target for industrial R&D: "The Committee has to recognize, however, that the objective is not realistic if one considers only the recent trends in the performance of R&D by Canadian industry."[18] Since the trends have not changed significantly since the beginning of 1972, when Volume 2 was published, it is obvious that the objective appears even more unrealistic today. However, this is due to inaction, not to the impossibility of reaching that goal during the 1970s if the collective will had existed. The fact that our target has proven to be unrealistic should be a source of national concern rather than a reason to criticize our recommendation.

We have never suggested, as some of our critics have claimed, that the proposed targets should be attained by any means or at any cost. For critics who did not read the report we quote from Volume 2 our own interpretation of the meaning of our recommendations:

> The Committee wishes to emphasize, however, that its proposed target should at present be interpreted as a maximum objective to be achieved *only* if enough worthwhile programs and projects can be implemented. The additional effort should not be wasted on useless activities with no relation to public needs and priorities, such as large technological ventures selected purely under the influence of false notions of national prestige (what has been called "romantic technology") or because of the technological imperative, "'can' means 'must'." But if we did fail to meet the target because of a lack of useful programs that should be a cause for national concern, in view of what other industrialized nations are already doing in this respect. In the perspective of the new technology and its impact on growth and the quality of life, Canada will seriously suffer if it lags too far behind in the international scientific and technological competition, which will intensify during the present decade.[19]

In the context of this interpretation the Committee wants to reaffirm its recommendations on the size of the national R&D effort and its distribution between basic research and mission-oriented R&D. It is obviously too late now to expect that the proposed targets will be reached by 1980. But if governments and industry decide to act quickly these objectives could be achieved by 1985. We believe they could serve as broad guidelines during the next ten years to help the government determine the level and the main components of its own science budget.

A related recommendation in Volume 2 called for the government and Parliament to adopt an overall plan for science and technology in the 1970s. For the reasons just mentioned, we now propose that this planning period be extended to 1985. Practically all the briefs accepted the recommendation but doubted it could be successfully implemented until national goals and priorities were defined and an industrial strategy

adopted. We agree with this proviso but expect it will be easier to adopt an overall plan if MOSST develops a decision model and if the Department of Industry, Trade and Commerce is properly reorganized, as we have suggested in this volume. We hope also that in developing such a plan the government will carefully consider the approach and methods of France and West Germany.

INVENTORIES AND AUDITS OF R&D PROGRAMS

The Committee made four specific recommendations calling for a national inventory and audit of current R&D programs and projects supported by public funds and for a detailed and continuous review of the in-house R&D activities of departments and agencies. The Ministry of State for Science and Technology would be responsible for carrying out these proposals. We hoped that the national inventory, even if incomplete, would help identify gaps and undesirable duplication in the light of national objectives and strategies and that as a result of the continuing review of government in-house activities certain programs would be ended and others contracted out to universities or industry.

This set of recommendations received strong support in most of the briefs. The comment of one large Canadian firm was typical:

> We agree that this is one of the most important recommendations in the report, but every effort should be made to contract out mission oriented research to industry and let industry share this work with the universities on a sub-contract basis. There is a good case for continuing some of the work being done in-house, but these programs should be subjected to critical review by MOSST and involve representatives from industry and universities.[20]

There was some concern, however, whether MOSST could possibly have a staff of sufficient size and competence to conduct a national inventory and audit, and also whether proprietary information rights would be adequately protected.

On the basis of the Belgian experience in carrying out such an inventory, we are not too worried though we believe that adequate staff should be provided to do the job properly. These inventories, audits, and reviews are essential prerequisites if MOSST is to succeed in its new role in the central machinery responsible for assessing and approving the science budget and if Canada is to have a sensible medium-term plan for science, technology, and innovation.

On the second point, we believe there should be no compulsion to disclose projects that are fully funded by private sources although such disclosure should be encouraged; it is programs financed only or largely by public funds that ought to be reported.

THE TEACHING ROLE OF UNIVERSITIES AND THE NEEDS OF INDUSTRY

In Chapter 14 we recommended that "the responsibility for preparing university teachers and for supporting their research on the existing stock of knowledge designed to improve their teaching be left to provincial governments and universities within the framework of existing federal-provincial arrangements for the financing of post-secondary education."[21] Our purpose was to rehabilitate teaching as a major role of universities, to indicate how important research into the existing stock of knowledge is to good teaching, and to recall that teaching and activities directly related to education are matters of provincial jurisdiction.

Professional and industrial groups generally endorsed that recommendation without any detailed comment. A typical view was expressed by the Association of Professional Engineers of the Province of Ontario:

> We support the need for increased emphasis on teaching. However, we believe it is the responsibility of the university to integrate research primarily undertaken for teaching purposes, with that undertaken primarily for the advancement of knowledge.[22]

Many members of the academic community, however, reacted violently against the proposal. This attitude was not unexpected, especially if one takes account of the vested interest that pure scientists engaged in basic research have in the status quo. It was argued that in making such a recommendation the Committee was further downgrading basic research. It was said that the distinction between research on the existing stock of knowledge and research to increase that stock was confusing. It was also contended, even in some academic circles in Quebec, that to regard the training of teachers and the support of research directly related to teaching as an exclusively provincial responsibility would reduce the freedom of the academic community.

In the light of the first criticism, the Committee was pleased to see that its views were fully endorsed and further developed by the Bonneau-Corry report published in November 1972, *Quest for the Optimum: Research Policy in the Universities of Canada.* The study was made under the auspices of the Association of Universities and Colleges of Canada.

Dr. L.-P. Bonneau and Dr. J. A. Corry, two distinguished Canadian academics, agree that the first priority of universities is teaching, that is, the transfer to students of the existing stock of knowledge. They argue that this role has been neglected in Canadian universities and that basic research has become a "sacred cow." They propose to restore a balance by coupling teaching with a special type of research and by dividing scholars into two separate groups which would receive equal recognition

but according to different criteria. Dr. J. C. Polanyi has summarized their description of these two categories:

> In the first group (a purely arbitrary numbering) there would be the *frontier researchers*, whose activities bring substantial grants to the university. "Frontier research" is a new term, coined by the commissioners. It is intended to describe "research into things," "digging," "looking for nuggets of knowledge," "narrowly focussed minute analysis," "a heavy empirical undertaking." It is thought to be an activity that, because of the heavy demands it makes and the narrow focus it encourages, can easily detract from the quality of undergraduate teaching.
>
> The second, larger group of faculty would be engaged in what is termed *reflective enquiry*. This is conceived as another variety of research. . . . Reflective enquiry is distinguished by being "almost entirely an intellectual activity," "interpreting" rather than "searching." Instead of collecting new knowledge at the "frontier," the practitioner of this second category of research is reflecting in his study on "the larger meaning of what we know"; attempting in some measure to redraw "the map of knowledge." This second category of research is thought to be particularly suited to the improvement of undergraduate teaching. For this reason, it is to be mainly funded by the provinces, whereas frontier research would depend on federal support.[23]

As can readily be seen, if "basic research" and "research on the existing stock of knowledge" are regarded as synonyms for "frontier research" and "reflective enquiry," the views expressed in the Bonneau-Corry report are very similar to those we presented in Volume 2.

Recently considerable attention has been given to the relation between teaching and research in other countries. In the United States, the Carnegie Commission on Higher Education has published two reports, *Reform on Campus: Changing Students, Changing Academic Programs* and *More Effective Use of Resources: An Imperative for Higher Education.*

The first drew heavily on the findings of a survey of 70,000 undergraduates, 30,000 graduate students, and 60,000 faculty members made in 1969-70. While the Commission found no "deep academic crisis," it warned that it "may occur in the future, if needed reforms do not occur now." It noted that 95 per cent of the undergraduates, 89 per cent of the graduates, and 78 per cent of the faculty members thought teaching effectiveness, not research, should be the primary criterion for faculty promotion. Similarly a large proportion said courses should be "more relevant to contemporary life and problems." One of the main recommendations called for a "thorough review" of graduate education before any further expansion.

The second report suggested it would be necessary to get more work for less pay from faculty members by requiring them to teach bigger classes and spend more time in classrooms. It observed that staff members' interest in research often resulted in a proliferation of Ph.D.

programs, and suggested that Ph.D. training and federally supported research should be concentrated in a few institutions.

In short we can see that the diagnosis and prescription contained in the Bonneau-Corry report reflect emerging trends throughout the Western world. It is regrettable though not surprising that many members of the academic community have shown a negative attitude toward the report (the reflex described by Donald Schon as "dynamic conservatism"). Dr. J. Gordon Parr, chairman of the Committee on University Affairs in Ontario, briefly identified three reactions: "a plan, but not B-C; no plan at all; and the scientists' proud but undrafted plan." All three, he added, "appear to me to dodge the immediacy of the problem."[24]

He went on to suggest that these views were not as representative as they appeared to be:

> There is a realization in the academic community that times are yet to get harder; there is a view that some research is second rate by any standard; there is an occasional confession that graduate schools do not always insist upon excellence; and, praise be, there is a growing concern about effective learning and good teaching.[25]

The Committee hopes these concerns in the academic community will soon lead to remedial action. Dr. Parr considers one idea current among scientists, that "no solution is good enough"—another example of pure "dynamic conservatism"—and rejects it. We believe the rehabilitation of teaching in universities and of research on the stock of knowledge or "reflective enquiry" represents a valuable element in a solution. Those who disagree with this view must come up with a better alternative than the preservation of the status quo, or they will be the first victims of their own negativism.

The attempt to make university teaching "more relevant to contemporary life and problems" must take into account the needs of industry for properly trained and motivated scientists and engineers. Moreover, the research efforts of the academic and industrial sectors must become more interdependent and closer to each other than they have been in the past, while preserving their purposes and environments. This is more easily said than done, of course. Our recommendation was that MOSST sponsor a national conference of the two sectors to consider their complementary roles, to identify ways and means of helping each other, and "to devise the best possible permanent institutional basis for maintaining a continuing liaison and co-operation in the future."[26]

Dr. Alexander King, in his review of Volume 2, commented:

> As an OECD examiner of Canadian national science policy, I was very depressed by the lack of understanding and relationship between pure science in the universities and industry. Each side was critical, and often bitterly, of the other. Academics were distressed by what they considered to be well-nigh

complete lack of appreciation of scientific possibilities by industry, while industrialists bewailed the uselessness and snobbery of the academic product. We found this situation more aggravated than in most advanced countries and it seems to me to be one that requires a deliberate effort to rectify.[27]

While almost all the briefs recognized this problem and most also accepted the Committee's proposal, they pointed out that it was not easy to find a practical solution. The Electronic Industries Association of Canada (EIAC), for instance, stated that "this recommendation is almost totally supported" but warned that past efforts, notably the Canadian Organization for Joint Research, "have not been successful . . . mainly through lack of interest." The CMA also referred to past failures and warned: "Unless, therefore, there is one mechanism created to implement the best proposals, it would be pointless to hold a conference." The CCPA expressed the view that "a single conference would be unwieldy as a working body."

The pessimism revealed by these comments is probably exaggerated and may result in part from a misunderstanding of the nature and purpose of the proposed conference. The lack of interest shown in the past may not be as strong today. It appears that Canadian universities have passed their golden age as far as financial support is concerned. Many members of the academic community are worried about the future and realize their sector cannot be as autonomous as it was and continue to operate in its traditional splendid isolation. Canadian industry is increasingly aware that it cannot as easily rely on immigration to satisfy its need for qualified scientists and engineers, that it should become more interested in the scientific and engineering training received by young Canadians, and that it might with advantage rely more on research contracts and subcontracts with universities. So the time may be ripe for a successful meeting between the two communities.

The idea put forward by the Committee was not to hold another conference without adequate preparation or follow-up mechanism, but "to devise the best possible permanent institutional basis for maintaining a continuing liaison and co-operation in the future." A working group might well be asked to prepare reports on various institutional alternatives that could be discussed during the national conference, and preliminary regional meetings could consider the same issues. Eventually several institutions and mechanisms could be agreed upon, for it is doubtful whether a single channel would be sufficient to maintain continuing liaison and co-operation among a great number of independent units dispersed throughout a country of this size. We still believe that the conference we proposed would accomplish a most useful purpose.

SCIENTIFIC AND ENGINEERING MANPOWER TRAINING AND MOBILITY

The Committee made a number of recommendations on manpower requirements, training, and mobility. We proposed that MOSST appoint a task force to forecast the number and distribution of qualified scientists and engineers required by the industrial sector in 1970s. There was almost complete support for this suggestion. Alcan Aluminium Ltd. mentioned "periods of extreme distortion of the relationship between supply and demand for technically trained personnel" and the CMA asserted that if such estimates had been made in the past, the present surplus of trained people in certain disciplines might have been avoided.

Bell-Northern Research argued, however, that "industry cannot forecast its future requirements for QSE's because of the uncertain industrial environment." The Committee is aware of the shortcomings of forecasts but agrees with the APEO that they are useful as broad guidelines, even if they are not too accurate. Approximations are better than ignorance or hindsight. And of course the Committee is still concerned by the lack of data on the future needs for scientists, engineers, and technologists. Even now, manpower policy for highly skilled personnel appears to rest on three factors. First, universities tend to react too passively to demand pressure without adequately informing students of job prospects. Secondly, when scarcities develop, it is left to immigration to fill the gap. Thirdly, when surpluses occur in certain fields, it is assumed they will be absorbed by emigration, mainly to the United States, or that the specialists affected will be able to shift easily to other fields. This laissez-faire policy is creating tragedies for a growing number of young Canadians.

The Committee is pleased to note that MOSST has recently accepted this recommendation. We hope the task force will work in close collaboration with the Canadian Engineering Manpower Council, which has just completed a study of demand for Ph.D.s in engineering in Ontario, and with similar groups concerned with other disciplines. Collaboration is essential to the success of the undertaking. Moreover, when the study is completed it will be necessary to keep it up to date. This permanent service should be provided by the Department of Manpower and Immigration.

These forecasts should be publicized so that universities and students can also use them. It is imperative that they should be used to determine government scholarship and fellowships programs. Some years ago the National Research Council prepared forecasts that proved to be good approximations but the Committee is not aware that they had any significant impact on financial assistance programs.

This is why we recommended that MOSST "initiate a thorough reappraisal of all the Canadian government's scholarship and fellowship

schemes in the light of the current scientific and technological manpower situation and of the likely requirements . . . in the 1970s."[28] This proposal was also strongly supported in briefs we received. They pointed out that the re-appraisal should be done periodically in collaboration with "the appropriate professional organizations" and in the light of "relevance of national goals." We agree with these suggestions. In addition, we propose that in future these periodic re-appraisals be initiated by the Science Council and reviewed by MOSST in the exercise of its budgetary role and from its key position in the new central machinery for science policy.

Not only is it necessary to do whatever is possible to ensure an adequate and balanced supply of scientific engineering manpower in the future but we must also try to develop policies encouraging its greater mobility. The Committee therefore proposed that MOSST initiate a program in collaboration with the Public Service Commission and Treasury Board "to facilitate the mobility of R&D personnel within the government and between universities, industry and public agencies, with special emphasis on transfers from government to industry."[29] This recommendation too received strong support. One brief stated: "This is a most important proposal which could contribute considerably to the building of understanding between all sectors."[30] Another indicated that mobility would take care of itself, while an association warned that the difficulties in achieving it may have been underestimated.

We are inclined to accept the last point of view. There are obvious impediments to mobility which do not need to be enumerated here. People in general do not like to move and yet mobility presents great advantages not only for individuals but also for the collectivity. Remaining in the same job or environment for years may develop feelings of security but it also almost inevitably leads to a reduced sense of motivation and renewal. The chance to start another career can mean a new lease on life for the individual and new blood for the institution that would otherwise become paralyzed by the routine of an aging bureaucracy. It will take ingenuity and imagination to achieve greater mobility, but manpower transfers will ensure a more dynamic and creative scientific and engineering community in Canada.

STRATEGIES AND PRIORITIES FOR BASIC RESEARCH

Six of our recommendations dealt with strategies and priorities for basic research. The first proposed "a strategy emphasizing quality rather than quantity."[31] A few briefs rejected this suggestion, fearing, for example, it would lead to "overcontrol of curiosity-oriented science."[32] However, the great majority accepted it, even if with some reservations.

One brief argued that the recommendation "will require the development of criteria which are by no means simple, and the exercise of the most mature judgment."[33] Some process of appeal was advocated. The suggestion was made that "there must be limited provision for the training and cultivation of scientists and engineers who show potential, but who have not had the time to achieve 'the standard of international quality' referred to."[34] The danger of creating an "old boy network" was also mentioned. Some of these apprehensions are shared by the Committee but others arose because commentators considered each recommendation separately instead of as part of a package.

One consideration we had in mind when we made the proposal was that over the years an increasing capacity for basic research had been developed, partly as a result of growing government assistance. Thus there is now a substantial basis for building a strategy emphasizing high quality and thus allowing the provision of more generous support for excellence. This new approach, it might be hoped, would keep bright young Canadians at home and encourage notable foreign scientists to come here to pursue their careers.

We are bound to recognize the difficulty of evaluating the quality of basic research and judging the approach and intellectual rigour of an investigator. Stephen Toulmin in his book *Human Understanding* has some interesting comments on this topic.[35] He suggests that not only is there a difference between strategies of scientists in different areas but there are definite national styles of scientific endeavour. Men from different cultural and philosophical traditions might adopt conflicting intellectual priorities and see the "essential" rationality of science embodied in different policies. According to Toulmin, there are even differences of emphasis among research centres or schools in the same country and at the same time. He claims there are Cambridge geneticists and Edinburgh geneticists, Columbia operant psychologists and Harvard operant psychologists; and while one might sign on under either flag, it would be partisan to claim a monopoly of insight for either school. But a geneticist from Cambridge might prove to be an abrasive member of a peer group looking at research proposals put forward by Edinburgh geneticists.

One of the first comments on the striking difference between national styles in scientific theory was written by Pierre Duhem, who contrasted the manner in which the problems of electrical theory were handled by theoretical physicists in 19th-century France and Britain. He showed that at certain crucial points there were systematic differences in the strategies current among physicists in the two countries. In France, the accepted ideal was to cast all physical theories into axiomatic mathematical form. In Britain it was quite as much an ambition to develop models—even working models—by which physical phenomena could be

made intelligible visibly or tangibly rather than mathematically. These differences, Duhem argued, had parallels in other fields of thought: he cited literature, law, and the philosophy of science.

In Canada, where the scientific community comes from backgrounds both culturally and educationally diverse, its members must necessarily look through the filter of their past experience. There are bound to be considerable differences in approach and methodology.

Observers of creative scientists also find, not surprisingly, that like other people they can be jealous and ambitious. This point is well illustrated in James D. Watson's *The Double Helix* and by Robert K. Merton's studies of the behaviour of scientists. Peer groups have often been wrong. For example, a committee of peers considered Watson was not qualified to take advantage of the opportunities afforded by Cambridge University but he ignored their judgment and went on to win his Nobel prize.

All these difficulties mean that it is not easy to appraise the quality of basic research objectively. But there is no other alternative when the public funds available are insufficient to satisfy the requests of all applicants. Even in the best of possible worlds a granting system cannot be perfect. There is always room for improvement—and we made specific recommendations to effect it.

We are convinced the proposed Canadian Research Board and the three foundations as we conceive them would substantially improve the granting system. We also proposed that quality standards be based more on researchers' past performance than on their new applications for grants. This would make evaluation more straightforward and impartial. In our view it is easier to appraise results than promises coloured by "grantsmanship." We have suggested improvements to the peer system to prevent the "old boy network." These recommendations will not remove all the difficulties inherent in a granting system but they will help to increase the quality of basic research without leading to "overcontrol of curiosity-oriented science."

In another recommendation, the Committee provided for special assistance to scientists who showed potential but who had not had the time to achieve the standard of international quality. We refer here to our proposal that the foundations "continue or establish programs of post-doctoral fellowships awarded for a maximum period of five years."[36]

This suggestion was restricted to basic research carried out by young scientists in universities or similar institutions and was designed to compensate scholars for loss of salary resulting from the reduction of their teaching load. Most briefs received from professional and industrial associations considered the proposal too restricted. The APEO's reaction was typical:

> We endorse the recommendation if suitably enlarged to require that a prerequisite for such post-doctoral fellowships should be appropriate industrial experience, or alternatively that such post-doctoral fellowships should be tenable in an appropriate industrial establishment.[37]

The Committee cannot accept this suggestion as a general rule because the industrial environment is not usually regarded as appropriate for young scientists preparing to pursue a career in basic research. However, it may be desirable as an alternative for cases in which it is appropriate. In this connection, the Canadian Chemical Producers' Association suggests that the "NRC embryo scheme for post-doctoral fellowships in industry be retained and improved with a view to making them more attractive to industry."[38] We have already proposed that this assistance be integrated into a program under the Department of Industry, Trade and Commerce, and recommend the department to give careful consideration to the CCPA's suggestion. It has already been demonstrated that even basic scientists can, when they choose, operate effectively in large industrial laboratories. At least two Nobel prizewinners have conducted their work in such establishments in the United States.

Two other recommendations on priorities for basic research have been misinterpreted, largely because the wording used by the Committee was not clear enough.

We proposed that the foundations, applying the criterion of social merit, "assist only those [projects] that are relevant to the Canadian scene [and] reject Big Science projects to be carried out with Canadian support alone."[39] While most professional and industrial associations accepted that only basic research relevant to the Canadian scene should be supported by public funds, this criterion caused some concern in scientific circles. In the Committee's eyes, relevance to the Canadian scene was not so much a matter of exclusion as of priority. We were trying to apply the principle of the international division of labour even in the sector of basic research. For instance we believe it is more appropriate for Canada to support basic scientists studying Arctic ecology than the ecology of desert regions. In our view this is a valid consideration when funds are limited. But we agree that this criterion should be used only in extreme cases and that scientific merit should generally prevail.

There was some confusion about the expression "Big Science projects." Here we used the word "science" in its restricted sense, as opposed to technology, and we meant basic science programs requiring expensive, specialized equipment. The most commonly cited cases are in astronomy, where large optical equipment and telescopes are needed, or particle physics, where expensive accelerators are required.[40] It is obvious that Canada cannot afford to equip its scientists for such big basic science projects. We also feel, however, that Canadian basic scientists should not be prevented from participating in such huge programs and

that is why we suggested the government should seek the collaboration of other nations. The Franco-Canadian financing of the telescope in Hawaii is a good case in point.

The other recommendation said:

> At least during the 1970s the order of priority in government support for curiosity-oriented basic research should be, first, the social sciences and the humanities, and second, the life sciences, mainly those related to human health, provided of course that international standards of excellence can be developed and achieved in these areas.[41]

This proposal created a good deal of confusion and controversy. Many individual scientists and groups agreed with it. One brief from a large private firm stated:

> We believe that this recommendation deserves vigourous support. While the desired shift in emphasis must, for practical reasons, be gradual we believe that emphasis on the social sciences, humanities and life sciences should be increased at as rapid a pace as is possible.[42]

Others, however, strongly disagreed. One brief commented that the physical sciences are "presumably left low down on the scale of priorities and we wonder what type of research projects are to receive major financial support among the social sciences. It appears to our organization that the social well-being of Canadians depends so much on a sound economic foundation that the strong emphasis on supporting philosophical research may result in some deterioration in the Canadian standard of living."

The main concern was that the priority assigned to the social sciences and humanities would downgrade the physical sciences. The Committee wishes to emphasize that the physical sciences should not be weakened and that the public support allocated to genuine basic research in this area would increase if all our recommendations regarding R&D targets and strategies were implemented. We fully endorse the comment made by the Canadian Council of Professional Engineers:

> We believe it is unwise to neglect present strengths in the natural sciences and would prefer to see increased emphasis and additional support to the social sciences and humanities and the life sciences without diminishing the attention given to the natural or physical sciences.[43]

If the foundations concentrated on post-doctoral fellowships, on genuine basic research, and on quality rather than quantity, as we suggested, their constituency would be considerably reduced by comparison with the coverage they are presently attempting. They would then be in a position to encourage excellence in the three main discipline areas much more generously, even if their budgets were to remain unchanged. However, the Committee developed its priorities within the framework

of its proposals that 2.5 per cent of the GNP could be usefully spent on R&D activities by 1980 and 10 per cent of that amount should be devoted to basic research. In that context, we feel that even giving top priority to the social sciences there would be enough funds left to support all worthwhile projects in the physical sciences adequately.

RESEARCH ON RESEARCH: RESEARCH MANAGEMENT TRAINING

The Committee observed that there was an urgent need to improve the training of R&D managers and to do more research on the R&D and innovation processes.[44] We recommended MOSST to collaborate with representatives of university schools of management and the Canadian Research Management Association (CRMA) in developing a training program for R&D managers and research in scientific activities.

Dr. M. P. Bachynski and the members of the CRMA gave this matter considerable attention at their annual conference in October 1972. The association sought the reaction of 53 senior R&D managers; their response is contained in Dr. Bachynski's paper, "Training for the Management of R&D and Innovation in Canada":

> Of the respondents to the questionnaire, nearly 90% felt that there was a need to develop a program for improving R&D managers. . . . 80% of the respondents considered that there is a need for a research program in Canada on the organization of R&D activities and innovation strategies.[45]

About 75 per cent of those attending the CRMA conference were in favour of setting up a mechanism to develop a training program for R&D managers as recommended by the Committee. It is interesting to note, however, that only slightly more than half of those replying felt CRMA should name its own committee to help prepare and implement the program.

The conference then went on to consider our proposals for scholarships to be awarded in the field of R&D management and for the full financing of a MOSST research program on research. The paper states:

> More than 80% of the respondents were *against* the establishment of a scholarship program related to the training of R&D managers. However, 70% favour it that MOSST or some other government department provide full funding of the research programs. Many felt that MOSST should not participate actively, only fund the programs.[46]

Several briefs commented on the CRMA. The CMA brief warned that "the Canadian Research Management Association is not at present organized to carry out full time assignments or to receive grants."[47] The EIAC brief indicated "moderate support to these recommendations" but

added: "to a considerable extent they are unrealistic in view of the present organization and scope of the Canadian Research Management Association."[48] Bell-Northern Research stated:

> This could be a valuable exercise but CRMA does not have a secretariat to carry it out. It is not clear how the required co-operation between industry and university can be accomplished. CRMA lacks strong industry representation.[49]

The Canadian Electrical Manufacturers Association's brief agreed to university-based courses and recommended that they be instituted at one French-language and one English-language university as a beginning.[50] The Pharmaceutical Manufacturers Association of Canada agreed that the organization of forums where research managers could compare notes would be useful.[51]

The Association of Professional Engineers of the Province of Ontario presented an elaborate set of comments that deserve to be reproduced here:

> We endorse these recommendations with the proviso that the proposed training program be of a continuing nature and that it be restricted to graduate students who have obtained experience with some parallels to the Post-Industrial Experience Research Fellowship scheme, for example.
>
> We subscribe to the need for a greater component of engineering management in industry, a greater component of management trained persons in industry. We believe that scholarships in management training should be reserved for the mature student who has been working in industry for some time and who stands to be able to benefit from (say) MBA training to a much greater degree than an inexperienced student or a student on a strictly academic sequence.
>
> It is our feeling that there is a real need in government to train people to manage mission-oriented research and development activities, and all other processes which might be termed "innovative." We do not, however, believe that basic research requires the same approach.
>
> Government shared-cost business management training programs, conducted with industry co-operation, appear to be essential. We believe that such programs should be related geographically to industry concentrations where the ingredients of the course and the requirements of the industrial complex can be suitably co-ordinated.
>
> We suggest that the Minister of State for Science and Technology should take the initiative in establishing suitable fellowships in this area. We appreciate that the Ministry is not an "operating agency" and suggest further that the granting programs and the administrative activities relative to the fellowships be "farmed out" to an agency which has built up a substantial body of experience in such administration over many years.[52]

The response to its recommendations has further convinced the Committee that there is an urgent need for imaginative initiatives in this area. Obviously our proposals will have to be modified, at least as far as they involve the active participation of the Canadian Research Management

Association. But the apparent weakness of this group further indicates the scope for improvement in the training of research management and for the support of more and better empirical studies of innovation. These studies should cover the way scientific and technological knowledge is actually used; the development of indices to measure research performance in the aggregate as well as at the level of individual organizations; the relations between the organizational environment and research accomplishment, goal setting, and organizational planning; and the conditions for success in technological innovation. More solid information in these areas would not only help to improve our R&D performance and innovative ability but would also aid those responsible for formulating and implementing science policy. We urge MOSST to take the initiative and sponsor innovation studies, for without more adequate knowledge and better evaluation techniques the ministry will not be able to fulfill its new mission effectively.

CONCLUSION

On the evidence of these briefs and comments, there is a consensus for action on most of the recommendations considered in this annex or at any rate on some modified version of them. We hope these useful and encouraging views will be seriously considered by those who have the responsibility of acting on our suggestions.

The final message communicated to the Committee is an urgent call for action on a broad front to cope with present national conditions. This message has come loud and clear from all circles not bound to the status quo, the conventional wisdom, or the myths of the past. An extract from the joint brief presented by the Chemical Institute of Canada and the Canadian Society for Chemical Engineering reveals a typical sense of void and an impatient desire to fill it which are shared by many other dedicated Canadians:

> It is our view that Canada does not have, and has not had, a coherent science policy. The de facto science policy has been the sum of the individual policies of the various public and private sectors. For example, in recent years this "policy-by-accident" has resulted in emphasis on basic research, particularly in the physical sciences and particularly by governments and universities. The application of science to the solution of social and human problems and to the fostering of industrial innovation leading to economic growth has not received proportionate attention. Has this been in the long range national interest? Could these have been the priorities of a well-thought-out national science policy? We believe not. The recent in-depth studies of Canadian science policy by the Senate Special Committee on Science Policy, by the Science Council and others have developed sufficient information for formulation of a national science policy. Action is now required.[53]

The Committee fully endorses this statement. The responsibility now lies with governments and other Canadian decision-makers. They must respond quickly and imaginatively to the great challenge that science, technology, and innovation pose to Canada in the 1970s.

NOTES AND REFERENCES

1. The University of New Brunswick, "Comment on the Report of the Senate Special Committee on Science Policy, Volume 2: Targets and strategies for the seventies from the Faculty of Science."
2. Ibid.
3. *Targets and Stragegies for the Seventies, op. cit.*, p. 377.
4. University of New Brunswick, *op. cit.*
5. *Targets and Strategies for the Seventies, op. cit.*, p. 608.
6. Canadian Electrical Manufacturers' Association, Response to Volume 2.
7. Electronic Industries Association of Canada, *op. cit.*
8. The Association of Professional Engineers of the Province of Ontario, *op. cit.*
9. The Canadian Chemical Producers' Association, *op. cit.*
10. Electronic Industries Association of Canada, *op. cit.*
11. The Canadian Manufacturers' Association, *op. cit.*
12. *Targets and Strategies for the Seventies, op. cit.*, p. 377.
13. The Chemical Institute of Canada, Response to Volume 2 of the Report of the Senate Special Committee on Science Policy, June 3, 1973.
14. The National Science Foundation, *A review of the Relationship between Research and Development and Economic Growth/Productivity,* February 1971, p. 3.
15. Ibid., p. 3.
16. Ibid., p. 4.
17. Ibid., p. 3.
18. *Targets and Strategies for the Seventies, op. cit.*, p. 499.
19. Ibid., p. 421.
20. Bell-Northern Research, Comments on Lamontagne Report, Volume 2—Science Policy, October 1972, p. 11.
21. *Targets and Strategies . . . , op. cit.*, p. 439.
22. The Association of Professional Engineers of the Province of Ontario, *op. cit.*
23. "Rationalizing research in the universities: the Bonneau-Corry report". *Science Forum*, February 1973, pp. 4-5.
24. "An optimum solution is better than none at all," *Science Forum*, February, 1973, p. 2.
25. Ibid.
26. *Targets and Strategies . . ., op. cit.*, p. 522.
27. Alexander King. "The Lamontagne Report: An Erudite Approach to Science Policy Problems", *op. cit.*, p. 6.31.
28. *Targets and Strategies . . ., op. cit.*, p. 455.
29. Ibid., p. 596.
30. Alcan Aluminium Ltd., *op. cit.*
31. Ibid., p. 453.
32. Alcan Aluminium Ltd., *op. cit.*
33. Association of Professional Engineers of the Province of Ontario, *op. cit.*
34. Ibid.
35. Toulmin, *op. cit.*
36. *Targets and Strategies . . ., op. cit*, p. 453.
37. The Association of Professional Engineers of the Province of Ontario, *op. cit.*
38. The Canadian Chemical Producers' Association, *op. cit.*
39. *Targets and Strategies . . ., op. cit.* p. 456.

40. See our discussion in Volume 2, p. 385.
41. Ibid., p. 461.
42. Alcan Aluminium Limited, Comments on the Special Senate Committee Report on Science Policy in Canada. Volume 2, p. 9.
43. Brief to the Minister of State for Science and Technology and to the Senate Special Committee on Science Policy on the Report of the Senate Special Committee on Science Policy by the Canadian Council of Professional Engineers, May 19, 1972.
44. *Targets and Strategies . . ., op. cit.*, p. 529.
45. M. P. Bachynski. "Training for the Management of R&D and Innovation in Canada",Research Laboratories, RCA Limited, Ste. Anne de Bellevue, P.Q., pp. 3 and 5.
46. Ibid.
47. The Canadian Manufacturers Association, *op. cit.*
48. Electronics Industries Association of Canada, *op. cit.*
49. Bell-Northern Research, *op. cit.*
50. Canadian Electrical Manufacturers Association, *op. cit.*
51. The Pharmaceutical Manufacturers Association of Canada, *op. cit.*
52. The Association of Professional Engineers of the Province of Ontario, *op. cit.*
53. Chemical Institute of Canada and the Canadian Society for Chemical Engineering, Response to Volume 2, pp. 1-2.

ANNEX B

SCITEC'S RESPONSES TO VOLUME 2

Following the publication of Volume 2, the Association of the Scientific, Engineering and Technological Community of Canada (SCITEC) organized a response committee for the Senate science policy report. The committee made two surveys which were described by its chairman, Mr. R. C. Quittenton, as follows:

> . . . 44 technical societies were asked to appoint an official delegate to respond on the Senate Report to SCITEC, on behalf of the society concerned. Six members-at-large from the private sector were also asked to respond. The 44 societies selected were those who had participated in the founding meeting of SCITEC. Altogether, 110 delegates were invited to respond, as the "Official Response Committee." There are, however, now over 100 technical (scientific) societies in Canada. Thus this Official Response Committee clearly did not cover everyone. It did cover the major groups, however, such as the biologists, physicists, social scientists, medical doctors, chemists and engineers. This is the strength of SCITEC and, indeed, of the scientific, engineering and technological community of Canada.
>
> When the Senate Committee released their 45 recommendations from Volume 2, as summarized by the Senators, these were sent directly and unchanged to all the delegates with the request that they mark each recommendation either Approve, Reject or Abstain, and add any comments as desired.
>
> In an effort to broaden the sample, the same request was sent to the elected executives of several technical societies, various observers in industry, the universities and government, etc., as well as to the Council of SCITEC and to the Science Council of Canada. This whole group is called the "National Response Committee," comprising some 289 delegates. No real attempt was made to select these people on a fully representative basis. The attempt was rather to sweep in more responses from the scientific and technical fraternity, on an admittedly ad hoc basis. In tabulating the responses from this sector, however, the responses from the Official Response Committee were also included, to give an overall look. Thus the responses from the Official Response Committee are tabulated twice, once alone, and once with all the others in the National Response Committee.

Mr. Quittenton further explained that "112 opinions were received, from all across Canada and from virtually all disciplines." He produced a table showing the composition of the two samples.

RESPONSE SECTOR	SECTOR COMPOSITION				
	Academic	Industrial	Govern-ment	Basic	Applied
OFFICIAL RESPONSE COMMITTEE (Appointed Society Delegates)	21 55%	15 40%	2 5%	18 47%	20 53%
NATIONAL RESPONSE COMMITTEE (Official Response Committee, plus National Sample)	52 46%	38 34%	22 20%	44 39%	68 61%

The following tabulation represents the Committee's recommendations and the two responses expressed in percentages:

Summary of Recommendations	Official Committee			National Committee		
	Approve	Reject	Abstain	Approve	Reject	Abstain
	%	%	%	%	%	%
1. ... the Economic Council should enlarge its activities and establish a special Committee on the Future, with broad terms of reference but looking more specifically at the years 2000 and 1985 and attempting to project various possible environments that could emerge from the extrapolation of identifiable Canadian trends within the international context.	79	11	10	76	13	11
2. ... the Senate sponsor a conference for the purpose of establishing a Commission on the Future whose responsibility would be to help as many private and public organizations as possible to forecast and build their future not only in isolation but together.	71	16	13	65	23	12
3. ... the Canadian government and Parliament adopt an overall plan for the Seventies for science and technology, based on longer-term projections and overall national R&D targets, and that the procedures and organization of the planning, programming, and budgeting system be improved to provide a better assessment, of the output of R&D activities and a better basis for determining annual appropriations for the financing of such activities. We also recommend that by 1980 the approach be formalized in a framework of successive five-year plans.	89	8	3	82	9	9

Summary of Recommendations	Official Committee Approve	Official Committee Reject	Official Committee Abstain	National Committee Approve	National Committee Reject	National Committee Abstain
	%	%	%	%	%	%
4. ... the Ministry of State for Science and Technology be made responsible for keeping a national R&D inventory and be made responsible for developing a national audit of current R&D programs and projects being supported by public funds.	94	3	3	87	7	6
5. ... national expenditure on R&D should reach 2.5 per cent of GNP by 1980, it being understood that the Canadian government's direct contribution to reaching this target will be restricted to the support of worthwhile programs and projects.	65	14	21	69	10	21
6. ... a Canadian Research Board be set up, together with three foundations, to report to the Secretary of State and to be responsible mainly for the development of a capacity for and the support of curiosity-oriented basic research in universities and similar institutions;	63	21	16	60	19	21
7. ... the three foundations cover the physical sciences, the life sciences, and the social sciences and humanities, and bear the full cost, both direct and indirect, of the projects and programs they select to support in this area; and	55	26	19	58	20	22
8. ... the responsibility for preparing university teachers and for supporting their research on the existing stock of knowledge designed to improve their teaching be left to provincial governments and universities within the framework of existing federal-provincial arrangements for the financing of post-secondary education.	58	21	21	59	19	22
9. ... approximately 10 per cent of the national R&D effort be devoted to basic research by 1980 and that an immediate start be made toward this target.	58	21	21	56	17	27
10. ... the proposed foundations, in their efforts to develop and support excellence in curiosity-oriented research, follow a strategy emphasising quality rather than quantity;	87	5	8	81	10	9

Summary of Recommendations	Official Committee Approve	Official Committee Reject	Official Committee Abstain	National Committee Approve	National Committee Reject	National Committee Abstain
	%	%	%	%	%	%
11. ... they continue or establish programs of post-doctoral fellowships awarded for a maximum period of five years;	71	11	18	69	12	19
12. ... they provide research grants only to applicants who have demonstrated international quality standards in their past performance but that excellence be more generously rewarded and subjected to less administrative control; and	60	24	16	62	25	13
13. ... they improve their peer system, wherever necessary, to ensure the highest possible degree of competence and impartiality.	79	8	13	75	6	19
14. ... the Minister of State for Science and Technology initiate a thorough reappraisal of all the Canadian government's scholarship and fellowship schemes in the light of the current scientific and technological manpower situation and of the likely requirements of the new orientation that the national R&D effort will take in the 1980's. This study should be conducted in close collaboration with the proposed foundations and the Department of Manpower and Immigration.	84	8	8	83	8	9
15. ... the proposed foundations, in applying the criterion of social merit, turn down research projects or programs that involve undesirable duplication of others carried out elsewhere in the country or abroad and assist only those that are relevant to the Canadian scene. We further recommend that the foundations reject Big Science projects to be carried out with Canadian support alone.	47	42	11	47	37	16
16. ... at least during the 1970s the order of priority in government support for curiosity-oriented basic research should be, first, the social sciences and the humanities, and second, the life sciences, mainly those related to human health, provided of course that international standards of excellence can be developed and achieved in these areas.	34	39	27	33	43	24

Summary of Recommendations	Official Committee Approve	Official Committee Reject	Official Committee Abstain	National Committee Approve	National Committee Reject	National Committee Abstain
	%	%	%	%	%	%
17. ... the Minister of State for Science and Technology undertake a detailed review of the basic research activities carried out by all government agencies to see if they are justified and, if so, to consider whether some of them could not be advantageously transferred to universities;	79	13	8	81	11	8
18. ... in the future most basic research activities of the Canadian government be concentrated in a national research academy, with three institutes for the physical sciences, the life sciences, and the social sciences, with the purpose of filling gaps in basic research, especially in the social sciences and the life sciences; and	69	18	13	55	25	20
19. ... a substantial portion of the work of the institutes be performed at the request of government agencies and private firms on a fee basis.	63	16	21	59	17	24
20. ... the R&D activities performed by the industrial sector be substantially increased so that by 1980 they represent a maximum of about 60 per cent of the national R&D effort.	58	13	29	67	9	24
21. ... secondary manufacturing industries be requested by the Minister of Industry, Trade and Commerce to organize task forces, with proper labour representation, to consider the problems of scale and specialization and to prepare a plan within a year to improve the efficiency, the innovative capacity and the international competitiveness of individual firms through mergers or otherwise;	58	13	29	63	10	27
22. ... the minister appoint an impartial chairman and a small secretariat to assist each task force;	53	11	36	55	11	34
23. ... a special Cabinet committee be appointed under the chairmanship of the Minister of Industry, Trade and Commerce to examine, modify, and approve, after consultation with the interested provinces, the plans prepared by the industrial task forces; and	45	10	45	51	14	35

Summary of Recommendations	Official Committee Approve	Official Committee Reject	Official Committee Abstain	National Committee Approve	National Committee Reject	National Committee Abstain
	%	%	%	%	%	%
24. ... an Office of Industrial Reorganization, mainly composed of the chairmen and the secretariat of the task forces, be established to assist the Cabinet committee.	47	13	40	46	19	35
25. ... resource-based and primary manufacturing industries be requested by the Minister of Energy, Mines and Resources to organize specific task forces, with proper labour representation, to consider their innovative and R&D performance and within a year to prepare a plan to improve that performance in order to economize resources, utilize wastes more efficiently, reduce costs of production, discover new uses for their products, and further process these products in Canada for export.	65	5	30	73	4	23
26. ... the Minister of State for Science and Technology appoint a task force composed of representatives of universities and industry to estimate the number and distribution of QSEs that the industrial sector will require in the 1970s and to determine the qualifications and training they should have, in the light of the government decisions regarding targets and strategies for industrial R&D and innovation during the decade.	76	3	21	70	8	22
27. ... the Minister of State for Science and Technology sponsor a national conference widely representative of the academic and industrial sectors to consider their complementary roles in the national science, technology, and innovation effort, to identify ways and means of helping each other to accomplish their missions better, and to devise the best possible permanent institutional basis for maintaining a continuing liaison and co-operation in the future.	89	8	3	80	10	10
28. ... the Minister of State for Science and Technology set up a special committee with representatives from Canadian university schools of management and the Canadian Research Management Association to develop a training						

Summary of Recommendations	Official Committee			National Committee		
	Approve	Reject	Abstain	Approve	Reject	Abstain
	%	%	%	%	%	%
program for R&D managers and a research program on the organization of R&D activities and of innovation strategies;	71	8	21	72	13	15
29. ... the committee select Canadian centres in different regions to be mainly responsible for the proposed training program and choose the best qualified researchers to carry out the research program; and	60	3	37	65	11	24
30. ... the Minister of State for Science and Technology establish a program of scholarships to be awarded by this management training committee and provide the full financing of the research program and an annual grant to the Canadian Research Management Association to enable it to extend its activities in conjunction with the proposed programs.	58	3	39	64	11	25
31. ... all government departments and agencies which can have a significant but indirect impact on the industrial innovative process while serving their main missions, acquire the services of science policy advisers whose responsibility would include drawing attention to that impact when administrative decisions are taken and new policies are formulated;	79	4	16	74	10	16
32. ... the scope, composition, and authority of the Interdepartmental Committee on Innovation be enlarged to review, appraise, and discuss with the departments and agencies concerned the implications on the innovative process of their decisions and policies and, if necessary, to present recommendations to the Cabinet committee responsible for science policy; and	74	2	24	72	4	24
33. ... the Minister of State for Science and Technology be responsible for reporting to Cabinet the recommendations accepted by the Cabinet committee on these issues and that his staff provide the chairmanship and the secretariat of the interdepartmental committee.	66	2	32	66	4	30

Summary of Recommendations	Official Committee Approve	Official Committee Reject	Official Committee Abstain	National Committee Approve	National Committee Reject	National Committee Abstain
	%	%	%	%	%	%
34. ... all existing specific grants designed to encourage R&D activities in industry be integrated into one multi-purpose program, and be administered by the Department of Industry, Trade and Commerce in the light of the broad guidelines proposed for the determination and management of these subsidies; and	63	21	16	62	19	19
35. ... a lending and investing institution called the Canadian Innovation Bank (CIB) be created to support in co-operation with private venture capital companies the activities involved with the launching of technological innovations, especially in new or existing small and medium-seized firms, to provide managerial services to these enterprises and to be responsible to the Department of Industry, Trade and Commerce.	89	0	11	79	7	14
36. ... a detailed and continuing review be undertaken by the Ministry for Science and Technology of current and future industrial R&D programs of government departments and agencies involved with renewable resources and related primary industries such as agriculture and fisheries, and that the objectives of such a review be to make sure that these agencies do not get involved in R&D activities on manufactured goods based on primary products, abandon or reduce certain programs which have a low Canadian priority, and contract out their mission-oriented basic research to universities or to the National Research Academy, and as much as possible of their development work to industry;	58	10	32	68	11	21
37. ... the Ministry for Science and Technology undertake a review, with the same objectives, of industrial R&D programs in laboratories operated by government departments and agencies for secondary and service industries as well as for mining and power utilities;	69	2	29	76	5	19

Summary of Recommendations	Official Committee			National Committee		
	Approve	Reject	Abstain	Approve	Reject	Abstain
	%	%	%	%	%	%
38. ... on March 31, 1973, these latter government laboratories be brought together in a new Crown company called the Canadian Industrial Laboratories Corporation (CILC) with a strong industrial representation on its board and committees and a growing industrial contribution to its financing and to be responsible to the Department of Industry, Trade and Commerce; and	47	16	37	57	17	26
39. ... pending the results of the proposed detailed review, a financial and manpower limit be imposed on intramural industrially-oriented R&D activities, commencing in fiscal year 1973–74.	42	16	42	51	18	31
40. The Ministry of State for Science and Technology be given responsibility for initiating the creation of new scientific and technical information and transfer systems and technological forecasting services in co-operation with the proposed National Research Academy and the Department of Industry, Trade and Commerce and in consultation with the communication industry;	63	13	24	66	12	22
41. The main operating responsibility for the collection, storage, and dissemination of scientific and technical documentation should be assigned to the proposed National Research Academy, and the operating responsibility for the collection, storage, and effective transfer of information and technological forecasts concerning the industrial innovative process should be assigned to the Department of Industry, Trade and Commerce, while enabling other government agencies to maintain their own systems according to their specific needs;	63	7	30	64	13	23
42. The Ministry of State for Science and Technology be responsible for the continuing review and evaluation and co-ordination of the various government agencies' scientific and technical information and technological forecasting activities; and	84	0	16	85	3	12

Summary of Recommendations	Official Committee Approve	Official Committee Reject	Official Committee Abstain	National Committee Approve	National Committee Reject	National Committee Abstain
	%	%	%	%	%	%
43. All these activities be arranged so as to encourage the development of a Canadian information and forecasting industry to which the two ministries named above should give high priority.	74	2	24	77	4	19
44. The Ministry of Science and Technology review all scholarship and pre-doctoral fellowship programs sponsored by the Canadian government in light of projected QSE requirements for the 1970s, mainly in the technological sectors, including social engineering and business management, and with the view of eliminating emerging surpluses in certain areas and scarcities in others; and	76	5	19	70	14	16
45. The Ministry develop a program in co-operation with the Public Service Commission and the Treasury Board to facilitate the mobility of R&D personnel within the government and between universities, industry and public agencies, with special emphasis on transfers from government to industry.	89	3	8	90	1	9

On October 30 and 31, 1972, SCITEC held a conference on science policy in Ottawa. The main purpose of the meeting was to discuss the specific recommendations of Volume 2. The general conclusions were published in the February 1973 issue of *Science Forum* under the title: "The White Paper: the recommendations resulting from the forum."

While the conference agreed with the Committee's objectives, it expressed its concern "at the complex arbitrary organizational structures proposed in the report . . ." and made a plea for the status quo. It is intriguing to note this "dynamic conservative" reaction which is in sharp contrast with the two surveys SCITEC carried out. This is all the more surprising since it is reasonable to assume that the majority of those attending the forum had been included in the official and national samples. The only plausible explanation is that scientists, engineers and technologists speak with two voices, one for private reactions, one for public. The White Paper is reproduced here.

"The SCITEC Forum on Science Policy was held at the National Conference Centre, Ottawa, on 30 and 31 October 1972. The forum included participants from university, government, and industry, representing groups that are closely concerned with matters of science policy.

The major points emerging from discussions in the ten workshops and the plenary sessions were as follows:

PLANNING Delegates agreed that the solution of Canada's problems will call for more effective use of science and technology, but emphasized that science policy must be closely linked to the country's social, economic, and political objectives. They expressed concern about the effect that the large degree of foreign ownership has on the climate for industrial research and development in Canada.

There was a strong feeling that Canada should build on existing capabilities and achievements. The forum therefore expressed concern at the complex arbitrary organizational structures proposed in the report of the Senate special committee on science policy. Any new institutional structures should be based on a recognition of the continuum that embraces all stages, from basic science through applied science, development, and innovation. This might be achieved by establishing more multidisciplinary research and development groups with limited life and specific goals.

A national, total effort is called for to build up applied research and development in Canada, but this must be accomplished without losing sight of the great importance of basic research.

It is desirable to develop centres of excellence, but these cannot be achieved through the present mechanism of concentrating on grants to individuals. There are regional disparities in the opportunities to initiate and maintain such centres, and development grants could serve as a useful method to assist in their correction.

MANPOWER AND TRAINING The forum agreed that manpower needs should be assessed as precisely as possible, but it was aware of the fallible nature of manpower surveys. It emphasized that manpower studies could be performed most satisfactorily by representatives of the professional and scientific societies, because these are the groups closest to the problems.

Research is believed to be an integral part of the teaching process. Consequently, teaching and research in the university should not be separated.

PRIORITIES IN BASIC RESEARCH Delegates accepted that the need for more and better social science research justifies the high priority proposed for it, but they understood 'priority' to refer to the differential rate of growth of funding rather than to absolute amounts.

The forum expressed concern that certain areas of the life sciences for which the 'pay-off' to society may be very great are not receiving adequate support. An example is preventive medicine.

'Big Science' proposals should not be dismissed out of hand, especially if they have relevance or uniqueness for Canada or if support for them is available elsewhere in Canada or abroad.

BASIC RESEARCH IN-HOUSE The Ministry of State for Science and Technology should undertake a detailed inventory of the research activities carried out by all government agencies, for use as a management tool leading to decisions concerning the allocation of research projects between government, universities, and industry.

Most in-house basic research should not be concentrated in a National Research Academy as suggested in the Senate committee report. There may be a need, however, for a new national institute for the social sciences.

INDUSTRIAL TASK FORCES The forum agreed with the Senate committee report that Canada *must* improve its innovative capacity to maintain adequate economic growth. The first step is to improve the climate for industry, and the government has the requisite machinery to do this through the establishment of appropriate taxation, judicious tariffs, englightened labour laws, a strong patent system, adequate appropriate standards, tailored support programs, etc. To date this machinery has not been used effectively.

Although the forum agreed with the committee that task forces can play a useful role in facilitating dialogue on specific problems between government and industry, delegates believed that rationalization of industry would be beyond task forces' capabilities.

INDUSTRY-UNIVERSITY RELATIONS Industry-university relations should continue to be strengthened through existing mechanisms, such as the industrial research institutes and some of the projects initiated by the NRC. The universities should be encouraged to increase the amount of applied research they do through contracts from industry. The strengthening of university-industry interactions can be particularly relevant in helping to correct regional disparities.

INDUSTRY-GOVERNMENT RELATIONS The forum concurred with the principle of having science policy advisers for all government departments with a significant direct or indirect impact on industrial innovation (such as through buying power), as recommended in the report of the Senate committee.

It is also agreed that the terms of reference of the interdepartmental Committee on Innovation should be extended to include those departments whose policies may have a significant but indirect impact on industrial innovation. The committee should consult on a regular basis with industry (at least twice a year), circulate agenda and working papers to industry in advance of meetings, and foster close and continuous associations with industry through the medium of sub-committees or working panels on specific topics.

INDUSTRIAL INNOVATION Science policies aimed at encouraging innovation in industry will be effective only if action is taken to stimulate a favourable industrial climate. A sound technological assessment of the social and environmental effects of any proposed innovations involving major national developments must be an essential part of planning. The scientific and technological associations should share in this responsibility.

There was general concensus that there is a need for more venture capital and management services in this area but there is concern that a government-operated bank may not be the most effective mechanism for assisting innovative ventures. The policy of contracting-out more industrially oriented research was endorsed.

TECHNOLOGICAL INFORMATION A National Scientific and Technological Information Board, composed of delegates from the federal and provincial governments, universities, and industry should be given responsibility for devising ways of co-ordinating existing and potential resources that would comprise a National STI service. The board should evolve from the present NRC Advisory Board and should be given the necessary statutory and financial responsibility to carry out its functions. The Ministry of State for Science and Technology should be responsible for a continuing review, evaluation, and co-ordination of the scientific and technical information services and technological forecasting activities of the federal government."

ANNEX C

A LIST OF BRIEFS ON VOLUME 2

A large number of briefs commenting on the recommendations of Volume 2 were produced by various organizations and associations. Many were sent direct to SCITEC, presumably on a confidential basis. Government departments and agencies sent their comments directly to the Ministry of State for Science and Technology, also on a confidential basis. Some private associations presented their views to MOSST without communicating them to the Committee. Nevertheless, we have attempted to compile a list of these responses, and hope there are not too many omissions. The list does not include the many articles that appeared in newspapers, magazines, and journals.

Letter from THE CANADIAN MANUFACTURERS' ASSOCIATION dated February 5, 1971, signed by A. G. W. Sinclair, President.

Recommendations of THE LIBRARY COMMITTEE, SHERIDAN PARK, regarding the Lamontagne Report, dated February 19, 1971—Mr. B. M. Hewat, President.

Letter from THE ONTARIO CANCER INSTITUTE, Toronto, 12 February 1971, signed by H. E. Johns, Ph.D., Head Physics Division.

Initial Response of SCITEC to Vol. 2 of Senate Report on Science Policy.

SCIENCE COUNCIL OF CANADA, April 1972, Issues in Canadian Science Policy, A commentary on some aspects of Volume 2 of the Report of the Senate Committee on Science Policy.

MEDICAL RESEARCH COUNCIL Commentary on the Lamontagne Report, Volume 2, March 17, 1972.

THE CANADIAN COUNCIL OF PROFESSIONAL ENGINEERS, Ottawa. Brief to the Minister of State for Science & Technology and to

the Senate Special Committee on Science Policy on the Report of the Senate Special Committee on Science Policy, May 19, 1972.

THE CANADIAN MANUFACTURERS' ASSOCIATION—R & D Committee Working Paper (Revised comments on Senate Committee Report) Commercial Intelligence Department May 31, 1972 and October 20, 1972.

Science Policy in Canada. The Views of the CHEMICAL INSTITUTE OF CANADA and THE CANADIAN SOCIETY FOR CHEMICAL ENGINEERING—April 27, 1972.

Response to the Report of the Senate Special Committee on Special Policy—Vol. 2—Targets and Strategies for the 70's. THE ASSOCIATION OF PROFESSIONAL ENGINEERS OF THE PROVINCE OF ONTARIO May 31, 1972—Mr. W. L. Bradley, President.

ASSOCIATION CANADIENNE-FRANÇAISE POUR L'AVANCEMENT DES SCIENCES (ACFAS), Montréal, Canada. Some remarks on the report of the Senate Special Committee on Science Policy, June 1972. (copie française)

THE GEOLOGICAL ASSOCIATION OF CANADA, Toronto, Ontario. Brief dated May 20, 1972—Mr. Duncan R. Derry, President.

Lamontagne, Rothschild and Dainton—A review of three reports on aspects of Science Policy—Prepared for discussion at the 35th Meeting of Science Council by B. Belovic, R. W. Jackson, F. J. Kelly, J. Miedzinski and J. Mullen.

CANADIAN ELECTRICAL MANUFACTURERS ASSOCIATION, Toronto, Ontario. Brief dated August 18, 1972—Mr. F. G. Samis, General Manager.

Comments by ALCAN ALUMINIUM LIMITED, Montreal, Quebec, on the Special Senate Committee Report on Science Policy in Canada, Volume 2—August 24, 1972—J. F. Horwood, Vice-President, Technology.

Comments on the Report of the Senate Special Committee on Science Policy, Volume 2: Targets and Strategies for the Seventies, from the FACULTY OF SCIENCE THE UNIVERSITY OF NEW BRUNSWICK, Fredericton, N.B. September 10, 1972.

The response of the SOCIAL SCIENCE RESEARCH COUNCIL OF CANADA to a Science Policy for Canada—Report of the Senate Special Committee on Science Policy Volume 2: Targets and Strategies for the Seventies (Information Canada, Ottawa) 1972, September 20, 1972, October 3, 1972, Summary dated October 25, 1972.

BELL NORTHERN RESEARCH, Ottawa, Ontario—Comments on Lamontagne Report Vol. 2—Science Policy—October 1972—D. A. Chisholm, President.

Letter from the ONTARIO RESEARCH FOUNDATION, Sheridan Park, Ontario—September 29, 1972—C.R.G. Holmes, Department of Field Services.

THE CANADIAN MANUFACTURERS' ASSOCIATION, Toronto, Ontario Comments on a Science Policy for Canada—Report of the Senate Special Committee on Science Policy, Volume 2, Targets and Strategies for the Seventies, October 20, 1972.

Science Policy and Industrial Strategy—A response of THE PHARMACEUTICAL MANUFACTURERS ASSOCIATION OF CANADA to the report of the Special Committee (Lamontagne) on Science Policy of the Senate of Canada—October 1972—Wm. W. Wigle, President.

SCITEC Forum on Science Policy—October 1972—Workshop Reports. Summary of recommendations of the Senate Special Committee on Science Policy—as per Volume 2. (copie française)

Response to the Report of the Senate Special Committee on Science Policy, Volume 2, by THE ALBERTA SOCIETY OF PETROLEUM GEOLOGISTS, Calgary, Alberta—October 25, 1972—R. L. Slavin, President.

Brief to the Minister of State for Science and Technology and to the Senate Special Committee on Science Policy on the Report of the Senate Special Committee on Science Policy by THE ASSOCIATION OF CONSULTING ENGINEERS OF CANADA, Ottawa, Ontario, October 1972—Eric G. Jorgensen, President.

Comments on Volume 2 of Report of Senate Special Committee on Science Policy from ELECTRONIC INDUSTRIES ASSOCIATION OF CANADA, Ottawa, Ontario—November 6, 1972—Léon Balcer, President.

ADVISORY COMMITTEE ON BIOLOGY TO THE NATIONAL RESEARCH COUNCIL OF CANADA—7 and 8 November 1972.

Commentaires et recommandations de l'ASSOCIATION DES MÉDECINS DE LANGUE FRANÇAISE DU CANADA sur «Une politique scientifique canadienne»—11 septembre 1972.

Response to Volume 2 of the Senate Special Committee on Science Policy prepared by The Scientific Affairs Committee, CANADIAN PSYCHOLOGICAL ASSOCIATION THE UNIVERSITY OF WESTERN ONTARIO, London March 16, 1973.

Response to the Lamontagne Report by DEPARTMENT OF PHYSICS THE UNIVERSITY OF ALBERTA March 5, 1973—Dr. Sample, Chairman.

FACULTY OF SCIENCE THE UNIVERSITY OF WESTERN ONTARIO, London May 31, 1973—Andrew E. Scott, Dean. A critique of some aspects of "A Science Policy for Canada".

Response to Volume 2: Targets and Strategies for the Seventies Senate Special Committee on Science Policy prepared by THE AGRICULTURAL INSTITUTE OF CANADA October 1972.

Response to Volume 2 of the Report of the Senate Special Committee on Science Policy, 1972 prepared by the Science Policy Committee and endorsed by the Board of Directors of THE CHEMICAL INSTITUTE OF CANADA June 3, 1973.

BIBLIOGRAPHY

A

ALLEN, *Communication Patterns in Applied Technology*. The American Psychologist, November 1966.

ARGYRIS, Chris. Organizational Illnesses: Possible Cures. Lecture delivered at University of Toronto, October 15 and 16, 1968, sponsored by the Canadian Imperial Bank of Commerce and reprinted in *Commercial Letter* October 1968.

ARMER, Paul. Computer aspects of technological change, automation, and economic progress. *The Outlook for Technological Change and Employment*. Appendix to Vol. 1, U.S. Government Printing Office, Washington, D.C. February 1966.

AUJAC, H. Progrès technique et planification nationale. *Le Progrès Scientifique* nº 125, déc. 1968.

B

BABBITT, J.D. *Science in Canada, Selection from the Speeches of E.W.R. Steacie*. University of Toronto Press, 1965.

BACHYNSKI, M.P. Training for the Management of R&D and Innovation in Canada. Research Laboratories RCA Limited. Ste. Anne de Bellevue, P.Q.

BADGLEY, Robin F. Sociology in Canada: Past and Future. *Canadian Journal of Economics* February 1968.

BARFIELD, Claude E. Nixon reorganization raises questions about role of science in federal policy making. *National Journal* March 24, 1973.

BARZUN, Jacques. *Science: The Glorious Entertainment*. Harper and Row, New York, 1964.

BASIUK, Victor. The Impact of Technology in the Next Decades. *Orbis* Spring 1970.

BAZELL, R.J. Lead Poisoning: Zoo Animals May be the First Victims. *Science* Vol. 173, No. 3992 9 July 1971.

BELL, Daniel. The year 2000—The Trajectory of an idea. *Deadalus* Summer 1967.

BENN, Anthony Wedgwood. Towards a New Dictatorship? *Encounter* September 1971.

BIDERMAN, Albert D. Social Indicators and Goals. Edited by Raymond A. Bauer. *Social Indicators* The M.I.T. Press Cambridge, 1966.

BLACKBURN, Thomas R. Sensuous—Intellectual Complementarity in Science. *Science* 4 June 1971.

BLACKETT, P.M.S. Memorandum to the Select Committee on Science and Technology. *Second Report from the Select Committee on Science and Technology, Session 1968-69; Defence Research* Her Majesty's Stationery Office London 1969.

BLAKE, S.P. The Seven Pillars of Wisdom. *Science Journal* June 1969.

BLOOM, Justin L. Fast Breeder Reactors. *Scientific American* Vol. 223 No. 5 November 1970.

BOAS, Marie. *The Scientific Renaissance, 1450-1630*. Harper and Bros., New York, 1962.

BOK, B.J. *The Milky Way*. Harvard Books on Astronomy, Blakiston Co. Philadelphia, 1941.

BROECKER, Wallace S. Man's Oxygen Reserves. *Science* 26 June 1970.

BRONOWSKI, J. The Disestablishment of Science. *Encounter* July 1971.

BRONOWSKI, J. *The Western Intellectual Tradition*. Penguin Books, London, 1963.

BROOKS, Harvey. Knowledge and Action: The Dilemma of Science Policy in the '70's. *Daedalus*. Spring 1973.

BROOKS, Harvey. *The Government of Science*. M.I.T. Press, Cambridge, Mass., 1968.

BROOKS, Harvey. The Practical Uses of Pure Research. *New York Times* 12 January 1970.

BROWN, J.J. *Ideas in Exile*. McClelland and Stewart Ltd., Toronto, 1967.

BROWN, Lester R. Human Food Production as a Process in the Biosphere. *Scientific American* September 1970.

BURNS, T. *Main Speeches, Conference Papers*. Volume V, European Industrial Research Management Association, Paris, 1967.

BUTTERFIELD, Herbert. *The Origins of Modern Science*. Revised edition, The Free Press, New York. Paperback edition, 1965.

C

CAIRNCROSS, Sir Alec. Government and Innovation. *New Scientist and Science Journal* 2 September 1971.

CALDER, Nigel. *Technopolis, Social Control of the Uses of Science*. MacGibbon and Kee, London, 1969.

CALDER, Nigel. *Unless Peace Comes, A Scientific Forecast of New Weapons*. Viking Press, New York, 1968.

CANADA YEAR BOOK. *Astronomy in Canada*. 1965.

CANADA YEAR BOOK. *Mines and Minerals*. 1939.

CAREY, W.D. *Decision Making in National Science Policy*. "Science Policy Making in the United States", J. and A. Churchill Ltd., London, 1968.

CAREY, William D. The Need for Priorities. *Science* Volume 163 January 3, 1969.

CARRUTHERS, Jeff. Sensationalism at the NRC, or should the pot call the kettle black? *Science Forum* February 1973.

CAVES, Richard E. *Canadian Economic Policy and the Impact of International Capital Flows*. University of Toronto Press, 1969.

CHISHOLM, Dr. Donald A. Change and be Changed; The Road Ahead for R&D. *Telesis 2/1* Spring 1971.

CHISHOLM, Donald A. Thoughts on Innovation in Canada. Address to the Annual Meeting of the Association of Professional Engineers of the Province of Ontario, Hamilton Area Chapter May 6, 1971.

CHURCHMAN, C. West. *The Design of Inquiring Systems;* Basic Concepts of Systems and Organization. Basic Books Inc., London, 1971.

COGNARD, P. Pour une économie de la recherche. *Analyse et Prévision*, juin 1969.

COLE, LaMont C. Can the World be Saved? Dec. 27, 1967. Paper presented at the 134th meeting of the American Association for the Advancement of Science, published in *Bio Science* July 1968.

Comment favoriser la recherche par une meilleure collaboration entre l'Université et l'industrie. *Patronat Français* déc. 1966.

Communauté européenne élabore une politique commune de la recherche scientifique et technique (La). Presse et Information, Bruxelles, mars 1970.

COTTRELL, Alan H. *The Process of Technological Innovation*. "Technological Thresholds", National Academy of Sciences, Washington, 1969.

CRONYN. *Proceedings Cronyn Committee*. 1919.

CROOKELL, Harold. From Auto Pact to Appliance Pact—Steps Toward a Legislated Economy. *The Business Quarterly* University of Western Ontario, Spring, 1970.

CROOKELL, Harold. The Marketing Implications of Free Trade between Canada and the U.S. *The Business Quarterly* University of Western Ontario, London, Ont., Autumn, 1968.

CURTIS, Richard. *Perils of the Peaceful Atom*. Doubleday, N.Y., 1969.

D

DANIELS, George H. Technology and Culture. *The Big Question in the History of American Technology* Vol. II No. 1, 1970.

DAUD, B. Le financement de la recherche privée. II les mécanismes d'intervention de l'État. *Direction* février 1968.

DEHEM, Roger. The Economics of Stunted Growth. *Canadian Journal of Economics and Political Science* November, 1962.

DEPARTMENT OF AGRICULTURE. *Canada Agriculture, The First Hundred Years*. 1967.

DEPARTMENT OF MINES AND TECHNICAL SURVEYS. *The Dominion Astrophysical Laboratory*. Editorial and Info. Div.

de L'ESTOILE. Critères économiques de choix dans la politique scientifique et dans l'application de la science et de la technologie au développement. Réunion d'experts sur le rôle de la science et de la technologie dans le développement économique, Unesco, Paris, 18 déc. 1968.

de L'ESTOILE, H. La Programmation de la recherche appliquée: *méthode et critères*. P.S. nº 108, mai 1967.

de SOLLA PRICE, Derek J. *Is Technology Historically Independent of Science? A Study in Statistical Historiography*. Technology and Culture, No. 5, 1965.

de SOLLA PRICE, Derek J. *Little Science, Big Science*. Columbia U.P., 1963.

de SOLLA PRICE, Derek J. *Proceedings of The Israel Academy of Science and Humanities*. Volume IV, No. 6, "Measuring the Size of Science," Jerusalem, 1969.

de SOLLA PRICE, Derek J. *Science Since Babylon*. Yale U.P., 1961. Paperback edition 1962.

de SOLLA PRICE, Derek J. *Technology in Retrospect and Critical Events in Science*. December 15, 1968. Prepared for the National Science Foundation by the Illinois Institute of Technology.

de SOLLA PRICE, Derek J. *The Difference Between Science and Technology*. Thomas Alva Edison Foundation, Detroit, 1968.

DEUTSCH, Karl W. Conditions Favoring Major Advances in Social Science. *Science* 5 February 1971.

DOBROV, G.M. *Decision-Making in National Science Policy*. "Science Policy in the Soviet Union", edited by De Reuck, Goldsmith and Knight, A Ciba Foundation and Science of Science Foundation Symposium, J. & A. Churchill Ltd., London, 1968.

DOMINION BUREAU OF STATISTICS. *Federal Government Expenditures on Science, 1963-64 to 1970-71*. June, 1970. 6602-512. Advance Statement No. 1.

DOMINION BUREAU OF STATISTICS. *Industrial Research and Development Expenditures in Canada, 1965, 1967*. Catalogue Nos. 13-532 and 13-527, Queen's Printer, Ottawa.

DOUGLAS, Virginia, I. The Scientific Society's Look at Science Policy: A Summary of their Briefs. *Science Forum* Volume 6, No. 1 February 1973.

DRUCKER, Peter. 2000, Part V/The Plow and the Computer. Quoted by John Kettle, *Monetary Times* May 1967.

DRURY, Hon. C.M. *Government Stimulation of Technical Innovation by Canadian Industry*. Quebec City, October 10, 1967. Address to the semi-annual meeting of the Industrial Research Institute Inc.

DUBOS, René. *Man Adapting*. Yale University Press, 1965.

DUBOS, René. *Reason Awake: Science for Man*. Columbia University Press, New York, 1970.

DUBOS, René. *The Dreams of Reason, Science and Utopias*. Columbia University Press, New York, 1961. Columbus paperback edition, 1963.

DUPREE, A. Hunter *Science in the Federal Government, A History of Policies and Activities to 1940*. Harper Torchbook, New York, 1964.

DURA, J. L'Économie de la recherche sur une mauvaise voie. *Économie politique* janv. 1969.

E

EASTLAND, Bernard J. The Prospects of Fusion Power. *Scientific American* Vol. 224, No. 2 February 1971.

ECONOMIC COUNCIL OF CANADA. *The Challenge of Growth and Change*. Fifth Annual Review, Queen's Printer, Ottawa, 1968.

EGGLESTON, W. *Canada's Nuclear Story*. Clarke Irwin, Toronto, 1965.

EGGLESTON, Wilfrid. *Scientists at War*. Oxford University Press, Toronto, 1950.

EHRLICH, Paul R. and Anne H. *Population Resources Environments: Issues in Human Ecology*. W.H. Freeman and Company, San Francisco, 1970.

EULER, Hon. W.D., Chairman of the Privy Council Committee on Scientific and Industrial Research. *The Organization of Research in Canada*. Ottawa, March 19, 1938. Submission by the National Research Council to the Royal Commission on Dominion Provincial Relations.

EUROPE, COUNCIL OF. *Non university research centres and their links with the universities*. Council for cultural Co-operation, Strasbourg, 1967.

EVANS, W.G. *Wealth from Knowledge: Studies of Innovation in Industry.* MacMillan, London, 1972.

F

FISHER, Harold W. *The Process of Technological Innovation.* "Innovation in a Large Company", Washington, 1969.

FISHERIES RESEARCH BOARD OF CANADA. *Fishes of the Atlantic Coast of Canada.* Bulletin 155, Ottawa, 1966.

FLEMING, Donald. Emigré Physicists and the Biological Revolution. *Perspectives in American History.* Vol. II, 1968.

FOSTER, J.S. *Base Load Application of Nuclear Power to a Mixed Hydro and Thermal System.* Paper presented at the World Power Conference, Sectional Meeting, Madrid, 1960. (Appendix A in Minutes of Proceedings and Evidence No. 25 of House of Commons Special Committee on Research, 1961)

FOWKE, Donald V. The Management of Uncertainty. *Cost and Management.* January-February, 1970.

France: profit rather than prestige is new policy for research. *Science* 26 September 1969.

FREEMAN, Christopher. *National Science Policy Physics Bulletin.* Vol. 20, 1969.

FREEMAN, Richard B. *The Market for College-Trained Manpower: A Study in the Economics of Career Choice.* Harvard University Press, Cambridge, 1971.

French science policy: New targets defined. *Science* 5 May 1967.

FROMM, Erich. *The Revolution of Hope: toward a humanized technology.* Harper and Row, New York, 1968. Also in Bantam Book paperback.

Future (the) of scientific and technical research in France. *Minerva* July 1970.

G

GABOR, Dennis. *Innovations: Scientific Technological and Social.* Oxford University Press, 1970.

GABOR, Dennis. *Inventing the Future.* Secker & Warburg, London, 1963.

GALSTON, Arthur. Crops without Chemicals. *New Scientist* 3 June 1971.

GARIGUE, Philippe. *Science Policy in Canada.* published by The Private Planning Association of Canada.

GEORGESCU-REOGEN, Nicholas. *The Entropy Law and The Economic Process.* Harvard University Press, Cambridge, 1971.

GIBBONS, M. *Wealth from Knowledge: Studies of Innovation in Industry.* MacMillan, London, 1972.

GILPIN, Robert. *France in the age of the scientific state.* Princeton University Press, 1968. Traduction Française en 1970: *La Science et l'État en France.* GALLIMARD. 414p.

GISCARD d'ESTAING, Valery. Pour une politique de la Science. *Atomes* nº 239, janv. 1967 et nº 241, mars 1967.

GLASSCO REPORT. *The Royal Commission on Government Organization.* Vol. 4, Queen's Printer, Ottawa, 1963.

GLOBERMAN, Steven. The Empirical Relationship Between R & D and Industrial Growth in Canada. An unpublished paper prepared at York University Toronto.

GOFMAN, John W. *Poisoned Power.* Rodale Press, Emmaus, Pa., 1971.

GOLDSMITH, M. *Decision making in national science policy.* Ciba Foundation, London, J&A Churchill, 1968. XIII + 309 p.

GOODSPEED, D.J. *A History of the Defence Research Board.* Queen's Printer, Ottawa, 1958.

GOUGH, William C. The Prospects of Fusion Power. *Scientific American* Vol. 224, No. 2 February 1971.

GROSS, Bertram M. The State of the Nation: Social Systems Accounting. *Social Indicators* edited by Raymond A. Bauer. The M.I.T. Press Cambridge 1966.

GUILLAIN, Robert. *The Japanese Challenge: The Race to the Year 2000.* J.B. Lippincott, New York, 1970. Original edition *Japon, Troisième Grand.* Les Éditions de Seuil, Paris, 1969.

GUMMETT, Philip. Assessing the Council for Scientific Policy. *Nature* Volume 240 December 8, 1972.

H

HACHEY, H.B. *History of the Fisheries Research Board of Canada.* Fisheries Research Board, Ottawa, 1965.

HADDEN, Dr. Jeffrey K. The Private Generation. *Psychology Today* October 1969.

HAEFFNER, Erik A. The Innovation Process. *Technology Review* March/April 1973.

HAGGERTY, P. Innovation and the Private Enterprise System in the United States. Address before the National Academy of Engineering, 24 April, 1968.

HAMMOND, R.P. Low Cost Energy: A New Dimension. *Science Journal* January 1969.

HANDLER, Philip. The Federal Government and the Scientific Community. *Science* Vol. 171, No. 3967 15 January 1971.

HARDIN, Garrett. The Tragedy of the Commons, *Science* 13 December 1968.

HARGER, Alan E. America's Technological Dilemma. *Technology Review* July, 1971.

HARRINGTON, Michael. *The Accidental Century.* Penguin Books, Baltimore, Maryland, 1966.

HARRISON, J.M. *The Geological Survey of Canada.* Canada Yearbook 1960.

HASKINS, Caryl P. Science and Policy for a New Decade. *Foreign Affairs* Vol. 49, No. 2 January 1971.

HERBLA, M. La Recherche: quelle stratégie fault-il adopter? *Direction* oct. 1967.

HERZBERG, Gerhard. The Dangers of Science Policy to the Creative Scientist. *Science Forum* February 1970.

HIBBARD, Walter R. *Transactions of American Society for Metals.* "Materials R&D: Planning, Programming, Budgeting and Measurement", Vol. LXII, March/June/September/December, 1969.

HILL, Albert G. *Public Television, A Program for Action.* "Technology and Television", Bantam Books, New York, 1967.

HOGAN, Elizabeth. *Perils of the Peaceful Atom.* Doubleday, N.Y., 1969.

HOLLOMAN, J. Herbert. America's Technological Dilemma. *Technology Review* July, 1971.

HOLLOMAN, J. Herbert. Diffusing Science from the White House. *Technology Review* March/April 1973.

HOLLOMAN, J. Herbert. *The Politics of Pure Science.* New American Library, New York, 1967.

HORNIG, Donald F. *Chemical and Engineering News* September 23, 1968.

HUBBERT, M. King. *Resources and Man.* "Energy Resources", W.H. Freeman and Company, San Francisco, 1969. A Study and Recommendations by the Committee on Resources and Man, U.S. National Academy of Sciences—National Research Council.

HUTCHINSON, Eric. Scientists and Civil Servants: The Struggle over the National Physical Laboratory in 1918. *Minerva* Vol. 8, No. 3 Spring 1969.

I

Impact of Science on Society. Social responsibility (I): The impact of Social responsibility on Science. Vol. XXI, No. 2, April-June, 1971.

ISENSON, R.S. *Technological Forecasting for Industry and Government.* "Technological Forecasting Lessons from Project Hindsight", ed. J.R. Bright, Prentice Hall, 1968.

J

JANTSCH, Erich. *Technological Forecasting in Perspective.* OECD. 1967.

JAPANESE AGENCY FOR SCIENCE AND TECHNOLOGY. *Summary White Paper of Science and Technology.* March, 1969.

JEVONS, F.R. *Wealth from Knowledge: Studies of Innovation in Industry.* MacMillan, London, 1972.

JOHNSON, Harry G. Canadian Contributions to the Discipline of Economics since 1945. *Canadian Journal of Economics* February 1968.

JONES, Graham. *The Role of Science and Technology in Developing Countries.* Oxford University Press, London, 1971. Published for the International Council of Scientific Unions.

JORDAN, Lloyd F. La Coordination des plans pour le progrès scientifique en Europe socialiste. ps nº 110, juillet-août 67.

K

KAHN, Herman. *The Emerging Japanese Superstate, Challenge and Response.* Prentice Hall, Englewood Cliffs, N.J., 1970.

KELLY, Frank. *Prospects for Scientists and Engineers in Canada.* Special Study No. 20. Science Council of Canada, January, 1971.

KING, Alexander. The Dilemma of Science Policy, *The Round Table.* No. 247, July 1972.

KING, Alexander. The Lamontagne Report: An Erudite Approach to Science Policy Problems. *Science Forum* April 1972.

KING, Norman. *La Politique Scientifique et les pouvoirs des parlements.* Centre universitaire des Hautes Études Européennes, 5 rue Schiller, Strasbourg.

KINZEL, Augustus B. *Man and His World: The Noranda Lectures, Expo '67.* "Industrial Research: Why, How, and What", University of Toronto Press, 1968.

KNIGHT, Julie. *Decision making in national science policy*. Ciba Foundation, London, J&A Churchill, 1968. XIII + 309 p.

KRONBERGER, Hans. *The New Scientists*. "How the Atom Paid Off", edited by David Fishlock, Oxford University Press. 1971.

KUHN, Thomas S. The Relations Between History and History of Science. *Daedalus* Spring 1971.

KUHN, Thomas S. *The Structure of Scientific Revolutions*. "Normal Science as Puzzle-solving", International Encyclopedia of Unified Science, Vol. 2, No. 2, University of Chicago Press, Second Edition, Enlarged, 1970.

L

LAKOFF, Sanford A. *Science* Volume 179, No. 4069 January 12, 1973.

LANGRISH, J. *Wealth from Knowledge: Studies of Innovation in Industry*. MacMillan, London, 1972.

LECANUET, J. Pour une politique de la Science. *Atomes* nº 239, janv. 1967 et nº 241, mars 1967.

LEONARD, William N. Research and Development in Industrial Growth. *Journal of Political Economy* March-April 1971.

LICKLIDER, J.C.R. *Public Television, A Program for Action*. "Televistas: Looking Ahead Through Side Windows", Bantam Books, New York, 1967. The report of the Carnegie Commission on Educational Television.

LILLEY, Samuel, *The Fontana Economic History of Europe*. "Technological Progress and the Industrial Revolution", Volume 3, London, 1970.

LOWI, Theodore, J. *The Politics of Disorder*. Basic Books, New York, 1971.

LUKASIEWICZ. *Complexity and Saturation in an Environment of High Technology*. College of Engineering, Virginia Polytechnic Institute and State University, Report VP1-E-70-21, December, 1970.

M

MACKENZIE, C.J. *Report to Prime Minister on Government Science*. Ottawa, 1964.

MACKENZIE, C.J. *The Significance of the Recent Scientific Explosion*. Montreal, Feb. 15, 1961. Address to the Chemical Institute of Canada.

MACKWORTH, Jane F. *Vigilance and Attention: A Signal Detection Approach*. Penguin Books, 1970.

MARQUIS, D. G. The American Psychologist. *Communication Patterns in Applied Technology* November 1966.

MARQUIS, D.G. *Successful Industrial Innovations*. National Science Foundation, NSF 69-71, Washington, 1969.

MARQUIS, D. The Knowledge Base for Education of Research Managers. Paper presented at the 19th National Conference on the Administration of Research, Denver Research Institute, April 1966.

MASLOW, Abraham H. *The Psychology of Science, A Reconnaissance*. Henry Regnery, Gateway Edition, Chicago, 1969.

MASSEY REPORT. *The Royal Commission on National Development in the Arts, Letters and Sciences*. Ottawa, 1951.

MAYER, Jean. Toward a Non-Malthusian Population Policy. *Columbia Forum* Summer 1969.

MAZLISH, Bruce. *The Western Intellectual Tradition*. Penguin Books, London, 1963.

MEADOWS, Dennis L. *Project on the Predicament of Mankind*. "The Flow of DDT in Environment from Chemical Plants to Biomass", The Club of Rome.

MEADOWS, Dennis L. and Donella H. *The Limits to Growth*. Universe Books, New York.

MEDAWAR, Sir Peter. The Pure Science. *The New York Times* June 24, 1973.

MEDICAL RESEARCH COUNCIL. *Canadian Medical Research, Survey and Outlook*. Ottawa, September 1968. Report No. 2.

MENCHER, A.G. Filtering Facts from Folklore (Part 1 of "Two Strategies for R&D Managers"). *Science Journal* June 1969.

MENCKE-GLUCKERT, P. Les objectifs de la politique scientifique officielle. *Analyse et Prévision*, sept. 1970.

MENDES-FRANCE, P. Pour une politique de la Science. *Atomes* nº 239, janv. 1967 et nº 241, mars 1967.

MERTON, Robert. *Science, Technology and Society in Seventeenth Century England*. Bruges, 1938.

MESTHENE, E.G. *Ministers talk about Science*. OECD, 1965.

MESTHENE, Emmanuel G. *Technological Change, New American Library*. New York, 1970.

MEYBOOM, Peter. *Technological Innovation in Canada*. Working Paper No. 7100, Department of Finance, Ottawa, 1970.

M.I.T. *Man's Impact on the Global Environment: Assessment and Recommendations for M.I.T.* The M.I.T. Press, 1970.

MONTAGUE, Peter and Katherine. Mercury: How Much Are We Eating? *Saturday Review* 6 February 1971.

MORTON, J.A. From Research to Technology. *The R&D Game.* edited by David Allison, M.I.T. Press, 1969.

MURRAY, John. *Synthetic Foods.* London, 1971.

MYERS, S. *Successful Industrial Innovations.* National Science Foundation, NSF 69-71, Washington, 1969.

Mc

McHALE, John. World Facts and Trends. *Futures* Vol. 3, No. 3 September 1971.

N

NATIONAL ACADEMY OF SCIENCES. *Physics: Survey and Outlook.* Washington, 1966.

NATIONAL RESEARCH COUNCIL OF CANADA. *Projections of Manpower Resources and Research Funds, 1968-72.* February 1969. A report of the Forecasting Committee.

NORICK, Sheldon. *The Careless Atom.* Houghton & Mifflin, Boston, 1969.

O

OCDE. *Écarts technologiques, Comparaisons entre pays-membres.* Vol. nº 8, rapport analytique, Paris, 1970. 331 p.

OCDE. *La politique de la Science en France.* L'observateur de l'OCDE, août 1966.

OCDE. *Politique Nationale de la Science.* France, 1966.

OCDE. Problèmes de politique scientifique. OCDE 1968—séminaire de Jouy en Josas, France, 19-25 févr. 1967.

OECD. *Canada.* Reviews of National Science Policy, Publication No. 26.223, Paris, 1969.

OECD. *R&D in OECD Member Countries: Trends and Objectives.* Document SP 71(10).

OECD. *The Conditions for Success in Technological Innovation.* Document SP(70).1, January, 1970.

OECD. *The Conditions for success in Technological Innovation.* Paris, 1971.

OECD. *The Growth of Output 1960-1980, Retrospect, Prospect and Problems of Policy.* December, 1970.

OECD. *United Kingdom and Germany.* Reviews of National Science Policy. Paris, 1967.

OETTINGER, Anthony G. *Run, Computer, Run: The Mythology of Educational Innovation.* Harvard University Press, Cambridge, 1969.

L'organisation de la recherche et la population des chercheurs. *Usine nouvelle* printemps 1970.

ORR, J.L. A Technological Strategy for Industrial Development. *Industrial Canada*, January 1969.

OSHIMA, K. Technological Innovation in Japan. *International Aspects of Technological Innovation.* Science Policy Studies and Documents No. 26, Unesco, Paris, 1971.

OSMOND, E. Making the Most of One's Own Resources—Research and Development. Paper read at a National Conference on Technological Innovation. University of Bradford Management Centre, 12th and 13th March, 1969.

OSTRY, Bernard. Sociology in Canada: Past and Future. *Canadian Journal of Economics*, February 1968.

OZBEKHAN, Hasan. *The Triumph of Technology: "can" implies "ought".* System Development Corp., Santa Monica, California.

P

PEELE, Gillian. The independent university faces the future. *The Financial Times* November 13, 1971.

PERROUX, François. *Recherche et activité économique.* Collection «U», Armand Colin, Paris, 1969. 508 p.

PEYREFITTE, A. Pour une politique de la Science. *Atomes* nº 239, janv. 1967 et nº 241, mars 1967.

PIGANIOL P. *Pour une politique scientifique.* Nouvelle Bibliothèque scientifique, Flammarion, Paris, 1963. 299 p.

PLATT, John. Conditions Favoring Major Advances in Social Science. *Science* 5 February 1971.

PLATT, John R. *The Steps to Man.* Wiley, New York, 1966.

POLANYI, Karl. *The Great Transformation, the Political and Economic Origin of Our Time.* Beacon Paperback edition, Boston, 1957.

POLANYI, Michael. *Criteria for Scientific Development.* "The Republic of Science", E. Shils, M.I.T. Press, Cambridge, Mass., 1968.

Politique (La) d'encouragement à la Recherche Scientifique et technique: de l'impulsion nationale aux réalisations régionales. *Les cahiers de l'Hexagone* nº 36, nov. 1967. 155 p.

Politiques de recherche et développement (Les). Association Française pour l'Accroissement de la Productivité, Cahier d'études nº 4, Paris, juin 1965. 125 p.

Politique de recherches, quelques aspects macroéconomiques. *Cahier d'Étude nº 8* de l'Association Française pour l'accroissement de la productivité, Paris, oct. 1967.

Politique scientifique en Europe (La). Communautés Européennes, Dossier bibliographique, Bruxelles, 1967. 54 p.

Politique scientifique et les relations scientifiques internationales (La). Colloque international. Université de Strasbourg, Centre Universitaire des Hautes Études Européennes, 5 rue Schiller, Strasbourg, 17 févr. 1967.

PORTER, John. *The Vertical Mosaic.* University of Toronto Press, 1965.

PRICE, Don K. Purists and Politicians. *Science* 3 January 1969.

PYKE, Magnus. A Taste of Things to Come. *New Scientist* 17 December 1970.

Q

Quelques aspects macroéconomiques d'une politique de recherche. *Cahier d'études* (AFAP) nº 8, oct. 1967.

QUINN, James Brian. Scientific and Technical Strategy at the National and Major Enterprise Level, Paper prepared for UNESCO Office of Economic Analysis, Symposium on The Role of Science and Technology in Economic Development, December 11-18, 1968. (available from Professor Quinn at Amos Tuck School, Dartmouth College).

R

RANDERS, J. *Project on the Predicament of Mankind.* «The Flow of DDT in Environment from Chemical Plants to Biomass», The Club of Rome.

REAGAN, Michael D. *Science and the Federal Patron.* Oxford U.P., New York, 1969.

Recherche et croissance Économique II. Conseil National de la politique scientifique. Belgique, 1968. 191 p.

Recherche (La) et le VIe plan. *Patronat* avril 1970.

Recherche Scientifique (La). L'État et La Société, Nº A2 de la Revue *Prospective,* Paris, Presse Universitaire de la Cité, 1965, 218 p.

Recherche (La) scientifique en France. Bulletin D.A.M. numéro spécial. Commissariat à l'Énergie Atomique, Paris, sept. 1969.

Recherche (La) en France et son développement indispensable. *Perspective* 4.2.67, 10 p.

Recherche scientifique et indépendance. (auteur anonyme), Lausanne, Centre de Recherches Européennes, 1965. 32 p.

Recherche (La) scientifique et la croissance industrielle. *Revue d'Économie politique,* Paris, mai 1965.

Recherche (La) scientifique et Technique. «Le cinquième plan». Commissariat Général du plan et équipement et de la productivité. Délégation générale à la Recherche Scientifique et technique. Deux volumes, 1966.

Recherche scientifique et technique en France en 1969. Assemblée Nationale. État récapitulatif de l'effort financier prévu au titre de la recherche en 1970. Projet de Loi de Finances 1970. Paris, Imprimerie Nationale, 1969. 105 p.

Recherche (La) scientifique, l'État et la Société. *Revue Prospective* nº 12. P.U.F., janv. 1965.

REUBER, Grant L. *Canadian Economic Policy and the Impact of International Capital Flows.* University of Toronto Press, 1969.

REUCK, Anthony (DE). *Decision making in national science policy.* Ciba Foundation, London, J&A Churchill, 1968. XIII + 389 p.

RITCHIE, Ronald S. *An Institute for Research on Public Policy.* December 1969 Information Canada 1971 CP32-13/1971. A Study and Recommendations prepared for the Government of Canada.

ROBERTS, E. The Myths of Research Management. *Science and Technology* August 1968.

ROSE, Hilary and Steven. *Science and Society.* Allen Lane, London, 1971.

ROTHSCHILD, Lord. *A Framework for Government Research and Development.* London, H.M.S.O., November, 1971.

RUDD, E. Rate of Economic Growth, Technology and the Ph.D. *Minerva* Spring 1968.

RUTSTEIN, David D. *The Coming Revolution in Medicine.* The M.I.T. Press, Cambridge, 1967.

S

SAFARIAN, A.E. *The Performance of Foreign-owned Firms in Canada*. Montreal, 1969.

SAINT-GEOURS, Jean. *La Politique économique des principaux pays industriels de l'occident*. Éditions Sirey, Paris, 1969. J11 + 576 p.

SAINT-PAUL, R. *Recherche et développement*. Dunod, Paris, 1966. XX + 198 p.

SAINT-SERNIN, B. Programmes et programmation. Les Problèmes d'organisation de la Science dans le monde moderne, Lord Bowden, *Le Progrès Scientifique* nº 113, 1967.

SALOMA, John S. *Congress and the New Politics*. "System Politics: the Presidency and Congress in the future", Little, Brown and Company, Boston.

SAMUELSON, Paul A. *The New Economics: Keynes' Influence on Theory and Public Policy*. Edited by Seymour E. Harris, Alfred A. Knopf, New York, 1947.

SCANLON PLAN, THE. *A Frontier in Labor-Management Cooperation*. Ed. by F.G. Lesieur, The M.I.T. Press, Cambridge, 1958.

SCHON, Donald A. *Beyond the Stable State*. Temple Smith, London, 1971.

SCHUSTER, Richard P. *The Next Ninety Years*. Proceedings of a conference held at the California Institute of Technology, Pasadena, March, 1967.

SCIENCE COUNCIL OF CANADA. Annual Report 1971-72.

SCIENCE COUNCIL OF CANADA. Annual Report 1972-73.

SCIENCE COUNCIL OF CANADA. *Innovation in a Cold Climate*. Report No. 15, October, 1971.

SCIENCE COUNCIL OF CANADA. *Issues in Canadian Science Policy*. A commentary on some aspects of Volume II of the report of the Senate Committee on Science Policy. April 1972. The text of this commentary also appeared as part of the Science Council's Sixth Annual Report.

SCIENCE COUNCIL OF CANADA. *The Role of the Federal Government in Support of Research in Canadian Universities*. Special Study No. 7, Queen's Printer, Ottawa, 1969.

SCIENCE COUNCIL OF CANADA. *Towards a National Science Policy for Canada*. Queen's Printer, October, 1968.

Science et Politique. nº spécial, nº 2, avril, juin 1966 de la revue *«les Études philosophiques»*, Presses universitaires de France, 1966.

SCIENCE SECRETARIAT. *Physics in Canada Today: Survey and Outlook*. Special Study No. 2, Queen's Printer, Ottawa, 1967.

SCIENCE SECRETARIAT. *Psychology in Canada*. Special Study No. 3, Queen's Printer, Ottawa, 1967.

SEABORG, Glenn T. Fast Breeder Reactors. *Scientific American* Vol. 223, No. 5, November 1970.

SENGHAAS, Dieter. Conditions Favoring Major Advances in Social Science. *Science* 5 February 1971.

SHABAD, Theodore. Facility May Aid Subatomic Study. *The New York Times* Monday, 18 October 1971.

SHAPLEY, Deborah. Technology Incentives: NSF Gropes for Relevance. *Science* March 16, 1973.

SHAPLEY, Deborah. White House Science: Hail and Farewell. *Science* Volume 179, No. 4080, March 30, 1973.

SHILS, Edward. Criteria for Scientific Choice. *Criteria for Scientific Development: Public Policy and National Goals*. M.I.T. Press, 1968.

SILBERMAN, Charles E. *Crisis in the Classroom: The Remaking of American Education*. Random House, New York, 1970.

SKOLNIKOFF, Eugene B. *Science, Technology, and American Foreign Policy*. The M.I.T. Press, Cambridge, 1967.

SKOLNIKOFF, Eugene B. *The International Functional Implications of Future Technology*. Los Angeles, Sept., 1970. Paper presented at The American Political Science Association Meeting.

SKOLNIKOFF, Eugene B. *The International Imperatives of Technology: Technological Development and The International Political System*. Research Series No. 16, University of California, Berkeley, 1972.

SMITH, Arthur J.R. The Social Sciences and the 'Economics of Research'. Address to the Royal Society of Canada, Calgary, Alberta, June 3 1968.

SMITH, H.A. *Base Load Application of Nuclear Power to a Mixed Hydro and Thermal System*. Paper presented at the World Power Conference, Sectional Meeting, Madrid, 1960. (Appendix A in Minutes of Proceedings and Evidence No. 25 of House of Commons Special Committee on Research, 1961)

SNOW, C.P. *Science and Government*. Mentor Books, Toronto, 1962.

Social Responsibility of the Scientist, The. Edited by Martin Brown, The Free Press, New York, 1971.

STEWART, Charles T. A Summary of the State-of-the-Art on the Relationship Between R&D and Economic Growth/Productivity. *A Review of the Relationship Between Research and Development and Economic Growth/Productivity.* National Science Foundation, February 1971.

STONE, P.B. *Japan Surges Ahead: Japan's Economic Rebirth.* Weidenfeld & Nicholson, London, 1969.

SUPPES, Patrick. The Uses of Computers in Education. *Scientific American* September 1966.

T

TAMPLIN, Arthur R. *Poisoned Power.* Rodale Press, Emmaus, Pa., 1971.

TARRENBAUM, M. *Coupling Research and Production.* "Study of Research/Engineering Interactions in Materials Science and Technology", ed. Martin and Willens, Interscience Publishers, 1967.

TAYLOR, G. Rattray. *The Biological Time Bomb.* Thames and Hudson, London, 1968.

TAYLOR, G. Rattray. *The Doomsday Book.* Thames and Hudson, London, 1970.

TEILHARD de CHARDIN, Pierre. *The Phenomenon of Man.* Collins, London, 1959.

THIEMANN, H. Science: a consequence of science policy or an expression of civilization? *Civilization & Science* A Ciba Foundation Symposium published by Elsevier Associated Scientific Publishers, New York, 1972.

THISTLE, Mel W. *The Inner Ring, The Early History of the National Research Council of Canada.* University of Toronto Press, Toronto, 1966.

THOMPSON, J.C. The Value of Weather Forecasts. *Science Journal,* December 1969.

TOFFLER, Alvin. *Future Shock,* Random House, New York, 1970.

TOULMIN, Stephen. *Human Understanding.* Volume 1: General Introduction and Part 1. Clarendon Press, Oxford, 1972.

TOUSCOZ, J. La recherche scientifique et le droit international. *Le progrès Scientifique* nº 111, sept. 67.

U

UFFEN, R.J. Recent Changes in Government Organization for Science Policy. *Science Forum* Vol. 2, No. 5 1969.

UNESCO. *La Politique scientifique et les états européens.* Conférence des ministres chargés de la politique scientifique des États-membres européens. Paris 22, 27 juin 1970. 180 p.

UNESCO. Le développement par la science. Essai sur l'apparition et l'organisation de la politique scientifique des États, 1969. 204 p.

UNESCO. Réunion d'experts sur le rôle de la science et de la technologie dans le développement économique. Paris 11, 18 déc. 1962.

UNESCO. *Statistiques de la Science et de la Technologie.* Aperçu mondial. Rapports et études statistiques nº 17, Édition bilingue français, anglais, Paris 1970. 66 p.

UNESCO. *The Application of Science and Technology to the Development of Asia: Basic Data and Consideration.*

UNITED KINGDOM. *A Framework for Government Research and Development.* H.M.S.O., London, November, 1971.

UNITED KINGDOM. *Committee of Enquiry into the Organization of Civil Science.* H.M.S.O. London, Cnmd. 2171.

UNITED KINGDOM. *The Prospects for the United Kingdom Computer Industry in the 1970s.* Fourth Report from the Select Committee on Science and Technology, Vol. 1, H.M.S.O., London, October, 1971.

University Independence: The Main Questions. Ed. John MacCallum Scott, Rex Collings, London, 1971.

U.S. DEPARTMENT OF HEALTH EDUCATION AND WELFARE. *A Strategy for a Livable Environment.* Govt. Printing Office, Washington, 1967.

U.S. GOVERNMENT. *Restoring the Quality of Our Environment.* Government Printing Office, Washington, D.C., November, 1965.

U.S. GOVERNMENT. *Technological Innovation: Its Environment and Management.* U.S. Gov't Printing Office, Washington, 1967.

U.S. GOVERNMENT. *The World Food Problem.* A Report of the President's Science Advisory Committee, Volume 1, May, 1967.

V

VILLECOURT, L. La Politique Scientifique de la France. *Sciences* mai-août 1967.

VILLECOURT, L. *Pour une politique scientifique.* Nouvelle Bibliothèque scientifique, Flammarion, Paris, 1963. 299 p.

VLACHY, Jan. Remarks on the Productive Age. *Teorie A. Metoda* II/3, Prague 1970.

VOLLMER, Howard M. Basic and Applied Research. *The Social Contexts of Research*. John Wiley and Sons, Toronto, 1972.

W

WALSH, Michael B. The Garbage Crisis: 'What can we do with it?' *The Ottawa Journal* 2 December 1968.

WALTERS, Dorothy. *Canadian Income Levels and Growth; An International Perspective*. Economic Council of Canada. Staff Study No. 23, Queen's Printer, 1968.

WATKINS, M. *Foreign Ownership and the Structure of Canadian Industry*. January, 1968. Report of the Task Force prepared for the Privy Council Office.

WATSON, James D. *International Science Policy*. "Potential Consequences of Experimentation with Human Eggs", Committee on Science and Astronautics, U.S. House of Representatives, Washington, 1971.

WATSON, James D. *The Double Helix; A Personal Account of the Discovery of the Structure of DNA*. Atheneum, New York, 1968.

WEINBERG, Alvin M. *Criteria for Scientific Development: Public Policy and National Goals*. "Criteria for Scientific Choice II: The Two Cultures", ed. Edward Shils, The M.I.T. Press, 1968.

WEINBERG, Alvin M. *Decision Making in National Science Policy*. "The Philosophy and Practice of National Science Policy", J.A. Churchill, London, 1968.

WEST, Allen S. Background Study for the Science Council of Canada. Special Study No. 25 *National Engineering, Scientific and Technological Societies of Canada* December 1972.

WESTGREN, Arne. *Nobel, the Man and His Prize*. Nobel Foundation, Elserier, 1962.

WIESNER, Jerome B. Science, Technology, and the Quality of Life. *Technology Review* December 1971.

WILLIAMS, Roger. Assessing the Council for Scientific Policy. *Nature* Volume 240 December 8, 1972.

WILSON, Andrew H. *Science, Technology and Innovation*. Economic Council of Canada, Special Study No. 8, Queen's Printer, Ottawa, 1968.

WILSON, J.T. Report of the President for the year 1972-1973. Presented at the annual meeting of the Royal Society of Canada at Kingston in June 1973.

WILSON, J. Tuzo. The scientific societies: what are they and what they should become. *Science Forum* April 1973.

XYZ

ZIMAN, John. *Public Knowledge: An Essay Concerning The Social Dimension of Science*. Cambridge University Press, 1968.

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